

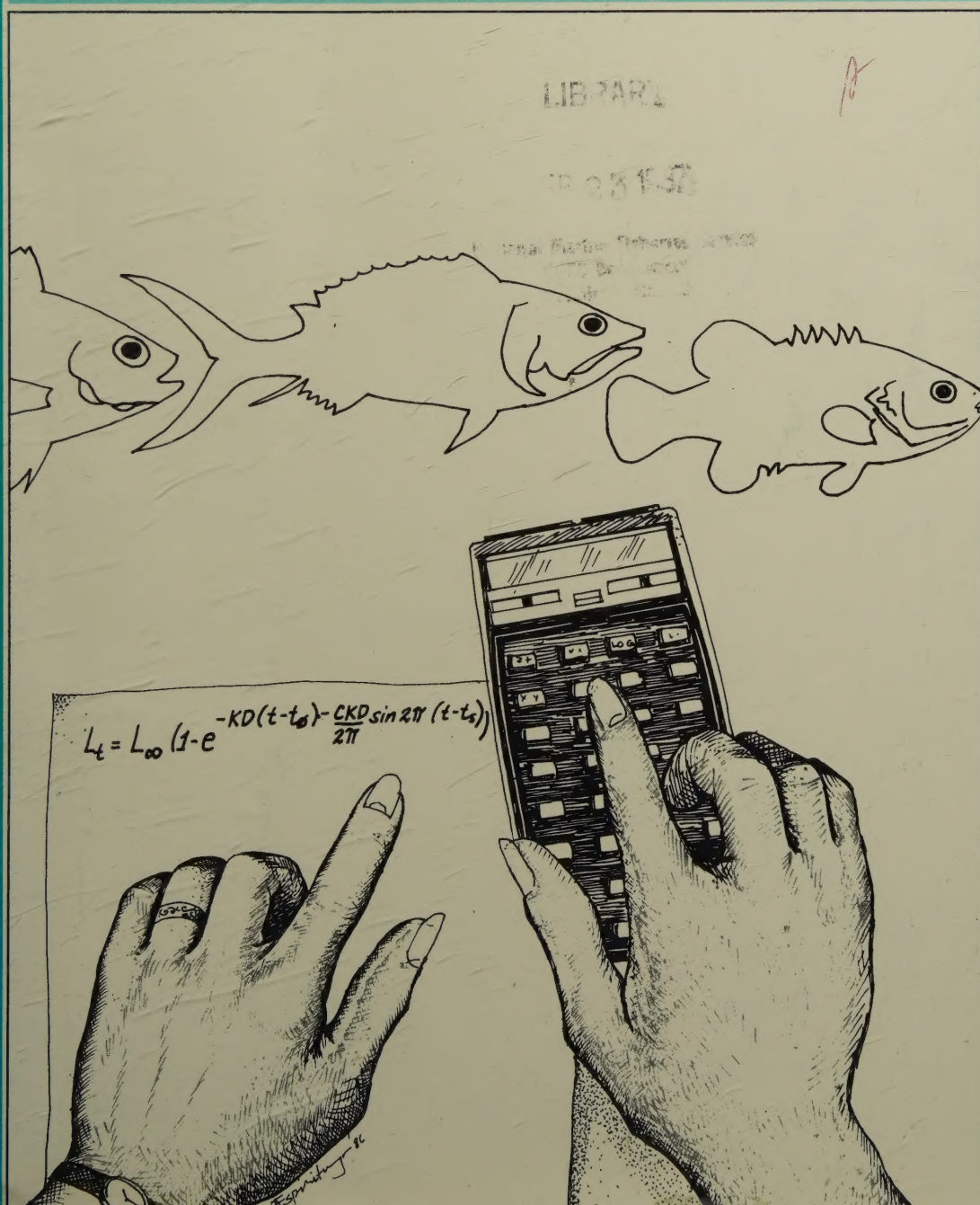
Computer programs for fish stock assessment

Applications for the HP 41 CV calculator

FAO
FISHERIES
TECHNICAL
PAPER

101

Suppl. 1



FOOD
AND
AGRICULTURE
ORGANIZATION
OF THE
UNITED NATIONS

Computer programs for fish stock assessment

Applications for the HP 41 CV* calculator

by

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Produced with the cooperation of the
International Center for Living Aquatic Resources
(ICLARM)

* This does not imply an endorsement of calculators
manufactured by the Hewlett-Packard Company

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PREPARATION OF THE DOCUMENT

The first issue of "Computer Programs for Fish Stock Assessment" compiled by N.J. Abramson in 1970, provided programs in FORTRAN for mainframe computers.* Another compilation is being prepared by the Fisheries Department, in BASIC, for personal computers as this inexpensive technology is now spreading rapidly to laboratories in developing countries.

The present document offers programs for simple assessment methods on the programmable pocket calculator HP41CV widening further the range of equipment and methodologies for which appropriate software is now made available.

The document has been prepared with the kind collaboration of the International Center for Living Aquatic Resources Management (ICLARM) which adapted for FAO the programs it has prepared for HP 67/97 (see reference in the abstract). It is recommended to refer to the original ICLARM manual for more details on methods, underlying assumptions and limitations.

* Additional or updated programs in FORTRAN have recently been compiled in:

Sims, S.E., Selected computer programs in FORTRAN for fish stock assessment.
1985 FAO Fish.Tech.Pap. (259):183 p.

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ABSTRACT

This document presents the conceptual and mathematical background, the user's instructions and the listings of a collection of thirty programs for Hewlett Packard HP 41CV (or equivalent) calculators, and covering the entire field of fish population dynamics.

Aspects given particular emphasis are (with number of relevant programs in brackets) length-weight relationships (1), mesh selection (1), growth (8), mortality (7, covering total, natural and fishing mortality), population size (notably 3 programs based on age or length-structured cohort and virtual population analysis), yield-per-recruit assessments (3), stock-recruitment relationships (2) and surplus yield models (3). Both single and multispecies assessments are discussed.

This document is intended to serve as a complement to and update of a more comprehensive text (Pauly, D. 1984. Fish Population Dynamics in Tropical Waters: A Manual for Use with Programmable Calculators. ICLARM Studies and Reviews 8, Manila, 325 p.), structured around HP67/97 calculators. Independent use of this document is made possible, however, through the inclusion of numerous computation examples and of tables with supporting data, all pertaining to tropical and/or subtropical fish stocks.

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FOREWORD

Rapid progress made in small computers technology over the last 10 years now offers modest laboratories in developing countries the possibility of gaining access to computing facilities similar to the ones used for a number of years in the working groups of the main Fisheries Commissions.

In these laboratories and for the scientist working generally in a critical scientific isolation, with very little assistance, small computers offer immense possibilities for progress towards understanding the techniques and models by self-teaching and experimenting, thus facilitating the lowering of physical and psychological barriers which kept many scientists away from the centralized main-frame computer systems.

The stock assessment manuals themselves should change in order to make better use of the opportunities thus offered, and the one prepared by Daniel Pauly of ICLARM^{a)} places them on the right track, offering, in a single volume, an extract of the theory, solved application examples, program listings and magnetic cards directly usable by the scientist.

As such, the manual is no longer a simple collection of techniques and becomes a real working tool.

FAO and the General Fisheries Council for the Mediterranean wished to obtain a version of the ICLARM manual adapted to the more powerful HP 41CV used in many laboratories in the region. This version, prepared by J. M. Vakily, M. L. Palomares and D. Pauly of ICLARM, presents the programs only and should be used jointly with the original and more complete ICLARM manual.

It is obvious that some of the techniques offered are far from perfect but unfortunately it is likely that some awkward or not-so-wise scientist will make errors by using inappropriate techniques or data not compatible with the underlying assumptions of the models used. I am however convinced that the benefits of easy access to computing facilities will largely outweigh the potential risks and, if I may borrow a now famous sentence, I consider that this document is a small step for fishery science but a large step for the development of the tropical scientific community.

S. Garcia

a) Pauly, D. (1984). Fish population dynamics in tropical waters: a manual for use with programmable calculators. ICLARM Studies and Reviews, 8, 325 p.

INTRODUCTION

This document presents 30 programs for fish stock assessment, implemented for use on HP 41C^{a)} programmable calculators^{b)}.

All of these programs are adaptations of programs for HP 67/97 programmable calculators, originally written by one of us (D.P.) and whose listings were included in a manual titled "Fish Population Dynamics in the Tropics: a manual for use with programmable calculators" (Pauly 1984), which from here on will be referred to as the "manual."

The manual discusses in detail the theory behind the various routines included in the present document; serious readers are advised to consult the manual. Using the programs included in this document without reference to the manual is possible, however. For this purpose, we have extracted from it and included here tables containing all the data necessary to implement and test all programs included here (see Appendix I).

These programs, numbered FB (Fishery Biology) 1 to 30, cover the following areas:

- Length-weight relationships (FB1)
- Gear selection (FB2)
- Growth (FB3 to 9)
- Mortality (FB10 to 15, and 17 to 20)
- Population size, Virtual Population Analyses (16-20)
- Yield-per-recruit assessments (FB21 to 23)
- Stock-recruitment relationships (FB24 and 25)
- Surplus yield and related models (FB26 to 29)
- Multispecies yields (FB30)

The selection of routines included here, which reflects that used in preparing the manual itself, is such that all routines selected can be applied to tropical and subtropical stocks of fish and invertebrates such as shrimps or molluscs. In the introduction to each program included here, original references are given to application examples (numbered 3.1 to 3.30) of the routine in question to such stocks. Also, the relevant pages of the manual are given, where the same, or a similar application example is illustrated.

General remarks on the models incorporated in the programs

About half of the routines incorporated in FB1 to 30 are based on "classical" models that are well-documented in the literature, notably in the widely-used texts of Ricker (1958, 1975) and of Gulland (1966,

a) The programs can be implemented on HP 41C, HP 41CV and HP 41X calculators. Details on these various implementations are given further below.

b) This does not imply an endorsement, either by ICLARM or FAO of calculators manufactured by Hewlett-Packard Company.

1983)). The other half are based on miscellaneous models developed in recent years by a number of authors (including the co-author of this document) explicitly for use in situations where data are sparse, and/or where the bulk of the available data are length-frequencies.

One major difference between the models included here and those found in textbooks is that we used here the "generalized" von Bertalanffy Growth Function (VBGF) sensu Pauly (1981), rather than the "special" VBGF proposed by von Bertalanffy (1934, 1938) and popularized by Beverton and Holt (1957). The generalized VBGF has for length the form

$$L_t = L_{\infty} (1 - e^{-KD (t-t_o)})^{1/D} \quad \dots 1)$$

and for weight the form

$$W_t = W_{\infty} (1 - e^{-KD (t-t_o)})^{b/D} \quad \dots 2)$$

where L_t and W_t are the length, respectively, the weight at age t , L_{∞} and W_{∞} the asymptotic length and weight, respectively, K and t_o constants estimated from growth data (along with the asymptotic size), b the exponent of the length-weight relationship and D the "surface factor" as defined in Pauly (1981). In the special case that $D = 1$, equation (1) reverts to

$$L_t = L_{\infty} (1 - e^{-K (t-t_o)}) \quad \dots 3)$$

i.e., to the "special" VBGF. When $b = 3$ and $D = 1$, equation (2) reverts, similarly to the special VBGF for growth in weight, i.e.

$$W_t = W_{\infty} (1 - e^{-K (t-t_o)})^3 \quad \dots 4)$$

as commonly used in fishery biology, and incorporated in a number of population dynamics model (notably the yield-per-recruit models).

The form of the generalized VBGF for growth in weight used here (equation 2) replaces the form of that equation in the manual, which was

$$W_t = W_{\infty} (1 - e^{-(3/b) KD (t-t_o)})^{b/D} \quad \dots 5)$$

the sole difference between equations (5) and (2) being the term $3/b$ which, rather than leading to a better match between the equations for growth in weight and growth in length (as was intended), led in the manual to several small but potentially confusing differences between results obtained by various models (see Appendix II).

A number of "bugs" were discovered in the original programs for HP 67/97, in the course of their translation for use with HP 41 family of calculators and in the text and figures of the manual. Included as Appendix II of this document is a list of errata of those non-obvious errors which lead to misunderstandings and affect the results of computations. It is hoped that the list is complete.

2. GENERAL INFORMATION ON PROGRAMS

2.1 System Overview

The package of 30 programs presented hereafter covers a broad range of methods applied in fish population dynamics in tropical waters.

Though they perform very different tasks, every effort has been undertaken to have all programs follow a common pattern in data manipulation. Menu, interactive operation, and annotated results should reduce the user's need to refer to the USER INSTRUCTIONS to the very minimum.

2.2 Hardware requirements

The programs are designed to run with Hewlett Packard Programmable Calculators belonging to the HP-41 system. A memory capacity of at least 319 registers is required. The following system configurations are acceptable:

- HP-41 CV
- HP-41 X
- HP-41 C with Quad Memory Module (HP 82170A)
- HP-41 C with 4 Memory Modules (HP 82106A)

A printer is not required. However, with a printer connected, most programs will provide the user with a hardcopy showing the program name, important input information (e.g. constants) and the results.

2.3 Capabilities/Limitations

2.3.1 "SIZE"-Configuration

Table 2.1 and 2.2 lists all programs and their respective requirements concerning data storage and program memory. To avoid frequent changes of the "SIZE"-configuration, a special feature is given in that setting SIZE 100 will allow to run almost all programs without difficulties (provided no other program is stored in memory). The only exception is Program FB 30.

Some of the programs require the storage of the original data set. Independently of the number of variables to be entered, all these programs are set to handle at least 30 cases. If more data are to be included, Tables 2.1 and 2.2 (p. 21 & 22) should be consulted for the necessary information on remaining storage capacity and corresponding "SIZE"-configuration.

2.3.2 Computation Time

Some programs compute the results via an iteration routine. This can take a considerable amount of time (the HP 41 does not have a 16 bit processor!). Depending on the number of cases involved, processing time of one hour or more can occur. In such cases - for the user's convenience - information is displayed on the current status of the computation.

2.3.3 HP-41 Display

Characters displayed by the HP-41 are quite limited both in their variety and in the total number that can be presented at a time. Even though the HP-41 can show messages longer than a 12-character string, the messages prompted by the programs are usually restricted to that size to avoid unnecessary loss of time while waiting for the message to be "pulled" accross the screen. As a consequence, it was necessary to abbreviate some of the messages to the extent that they might not be understandable anymore by themselves, but initially require the need to refer to the USER INSTRUCTIONS. It is expected, however, that, eventually this will become superfluous with the user becoming more familiar with the programs.

In the case of characters that can not be displayed exactly the way they should (mainly lower case letters beyond "e"), special signs - e.g. brackets "<", ">" - have been added to the appropriate character. Whenever in doubt, refer to the USER INSTRUCTIONS for the actual meaning.

2.4 **Getting Started**

There are three basic techniques for getting Programs FB1 to FB30 into a HP41CV calculator and ready to run:

- i) entering manually the listings included in this document (then if possible "saving" the programs onto magnetic cards or tape),
- ii) "reading"^{a)} preprogrammed magnetic cards using a HP82104A Card Reader,
- iii) "reading" the programs from^{b)} a prerecorded magnetic tape using a HP82161A Cassette Drive.

Manual data entry is a tedious and error-prone process (the program package presented here includes over 13000 (!) steps. Nevertheless, we have included complete listings for users with no access to periphery. Users wishing to enter programs should note the following:

- 1) You should be familiar with the content of your calculator manual,
- 2) You should at first experiment with a relatively short program (e.g., FB15),
- 3) When entering the program, pay special attention to the alphabetic strings. Many of these contain various numbers of SPACE commands (e.g., "F : " is entered as "ALPHA F SPACE : SPACE ALPHA").

a) The program package presented here requires 142 cards for storage, and would be rather expensive if supplied by either FAO or ICLARM. Users may wish to send empty cards to the Director, Resource Assessment and Management Program, ICLARM, MCC PO Box 1501, Makati, Metro Manila, Philippines, who, for a handling charge of 15 US\$ will have the programs copied onto the cards supplied, and the latter then airmailed back to the user.

b) Microdrive tapes (HP82176A) for the HP8216A Digital Cassette Drive containing the FB1 to FB30 programs can be supplied by ICLARM for 30 US\$ each. Please inquire at the address in above footnote.

- 4) All programs contain commands addressing a HP82162A Thermal Printer^{a)}; they can be entered only if a printer is connected via a HP82160A Module and turned ON. If a printer is not available, skip these steps (the program automatically bypasses printer commands if no printer is connected).
- 5) If you want to save the program onto a card, set flag 11 (SF 11), and do a "packing" (by pressing "GTO .."). Go to the end of the program and delete the final END statement. Then record the program onto a card (this procedure ensures program replacement and automatic start of new program upon reading the card(s)).

Reading of preprogrammed cards involves the following:

- 1) Turn calculator ON (make sure calculator is not in PRGM mode).
- 2) Select appropriate SIZE (see Table 2.1 and 2.2 and section 2.3.1 above), verify that flag 29 is cleared and flag 28 is set. If needed, clear flag 29 (CF 29) and set flag 28 (SF 28).
- 3) Then read cards. Program will start automatically.
- 4) If "NO ROOM" message appears, redo SIZE with a smaller number and/or delete any other program or key assignment still in memory (a simple way to achieve such deletion is to induce a "master clear", resulting in a "MEMORY LOST" message). A "master clear" is performed by switching the calculator OFF, then by pressing ON while simultaneously pressing the rub-out key (←) (after a master clear, you must repeat step (3)).

Reading the programs from a cassette tape involves the following:

- 1) Make sure that the calculator is connected to the tape drive via the HP82160A Module.
- 2) Turn the tape drive ON, then the calculator. Select appropriate SIZE (see step 2 above).
- 3) Verify that flag 29 is cleared, and flag 28 set. If necessary, clear flag 29 (CF 29) and set flag 28 (SF 28).
- 4) Insert cassette tape and press " ALPHA FB SPACE (n) ALPHA XEQ ALPHA READ P ALPHA."
- 5) Program will then start automatically.
- 6) A "NO ROOM" message may appear. In this case proceed as in step (4) above.

a) The HP82143A printer may also be operated in conjunction with a HP41 calculator, in which case no HP82160A Module (i.e., interface) is necessary. However, all "FMT" statements, used for centering the output of the new printer must be deleted from the programs (from the highest steps downwards and with HP82143A printer unplugged) if they are to be used with the older printer models. The "FMT" function appears in "PRGM" mode as "XROM 29, 25" in the display.

2.5 General Program Operation

2.5.1 Loading a Program

Select the appropriate SIZE configuration to create enough memory space for the program you want to work with. In most cases SIZE 100 will do. For detailed information on which SIZE to select, see Table 2.1 and 2.2. If the message appears: NO ROOM, repeat SIZE with a larger number. (Note: User-defined key assignments reduce memory capacity!)

When the programs are loaded into the calculator's memory by inserting the magnetic cards into the card reader (make sure the calculator is not in PRGM mode!), any previously loaded program belonging to this package will be replaced^{a)}. If program does not start automatically, press R/S ("RUN/STOP" key).

Except for FB 11 and FB 12, all programs will follow the same starting procedure: while displaying the respective program number, the calculator is initialized, i.e. all flags and registers are cleared, and USER mode is set. The system then presents the command help list (MENU) or - if there is no menu - the first prompt.

FB 11 and FB 12 are different in that they do not clear all data registers upon initializing.

2.5.2 The Menu

The menu is meant to give the user a short information on the keystrokes that have to be activated to access the various parts of a given program. It will not make it superfluous to initially study very thoroughly the USER INSTRUCTIONS. However, once familiar with the program, the menu should be sufficient to run a program.

There are two different sets of menu commands:

- General commands,
activated by the keys C, c, D, E
- Specific commands,
activated by the keys A, B, F, G, H, I, J

2.5.2.1 General Commands (C, c, D, E)

Every program contains up to four general commands which allow for convenient handling of routine work. Two of those (c, E) are incorporated in every program, whereas the other two are included only if the structure of the program requires it. There is no display of a "menu" if a program contains only general commands. In such a case refer to "REGISTERS, STATUS, FLAGS" to identify the commands used in the program in question.

a) This is so because programs FB1 to FB30 have an ".END." comment as the last statement (a program ending with "END" (i.e., without the dots) remains in memory when a new program is appended, which can be done only if enough memory is available for both programs).

Command : INITIALIZE
Assigned to : (f) c
Description :

This command initializes the program, i.e. makes it ready for the input of a new data set and/or the shift to a different part of the program. The command is equivalent to loading the program, i.e. all registers are cleared and flags and status are set.

Command : REVIEW MENU
Assigned to : C
Description :

If a program contains "Special Commands", a menu is included which shows these special commands together with the general commands. The menu is displayed right after loading (or initializing) the program, or - in some cases - after the initial input of data. Pressing "C" recalls the menu at any time. It should be noted, however, that the program will not resume its procedure at the position where it was before the menu was called. To restart a program, any of the commands offered has to be selected first.

Command : REVIEW DATA
Assigned to : D
Description :

This command is used in programs which store the original data set. For data already entered (i.e. after R/S has been pressed), any correction is done after the complete data set has been entered. (Note that every program will automatically call this routine after completion of data entry.)

Prompts : ROW NO. ?

The user is first asked to indicate the number of the row she/he wants to check for erroneous data entry. After entering a specific row number all variables will consecutively be displayed with their respective values recorded in this row. This is followed by the question:

CORRECTION ?
YES: 1, NO: 0

If the user specifies "1", the next prompt is:

CORR. INPUT :

followed by the name of the first variable. The user has to enter the correct value of this and all other remaining variables of the respective row (Note that all values have to be re-entered). Next prompt is:

MORE REVIEW ?

(The same prompt appears if the user had specified "0" <zero> after the preceding question to indicate that no correction was necessary.)

YES: 1, NO: 0

Specifying "1" will bring the user back to the beginning of the correction routine.

Specifying "0" makes the system leave the correction routine.

Command : REVIEW INPUT
Assigned to : D
Description :

In contrast to the command described before, "Review Input" is used in programs which do not store the original data set, but still have to handle a considerable amount of data. It allows to review the preceding input and - if necessary - to correct it. There is no correction routine offered at a later point. (But note that this routine will automatically be called after the user has entered the last row of data.)

Prompts : LAST INPUT :

This will be followed by the display of all variables and their corresponding values which had been entered with the last R/S command. The user then will be asked:

CORRECTION ?
YES: 1, NO: 0

By selecting "1", the user can correct the preceding data set by re-entering all data. After the selection of "0", the user is asked to enter data of the following row.

Command : REVIEW RESULTS
Assigned : E
Description :

Computed results are displayed automatically. This is done either step by step or continuously. In the first case, the user is required to enter the R/S command to display results in succession, whereas in the latter case results are displayed with only short interruptions (of about two seconds). The results can be reviewed by pressing "E". If different sets of results were computed, only the very last one is displayed.

2.5.2.2 Special Commands

(A, B, F, G, H, I, J)

The special commands are needed to select those parts of the programs the user wants to work with. Their function is explained in the USER INSTRUCTIONS and also mentioned in the menu.

Note: If a part of a program has been completed and the user wishes to switch to another part of the same program, she/he usually will have to initialize the system by pressing "(f)c". For exceptions see the USER INSTRUCTIONS.

2.5.3 General Features

In the following, a short overview is given of the general structure most programs are based on, and of some features that have to be dealt with.

Typically, a program has the following structure:

Initialization
Menu
Program Selection
Data Input
Review and Correction
Computation
Result Display

The selection of a program is followed by the input of data (constants, and/or variables). This procedure is usually started with the question:

NO. OF ROWS ?

which requires the input of a figure representing the number of rows (i.e., cases) the user intends to enter. (The number of variables is provided by the program itself.)

When entering the data the user generally receives first information on which row he or she is working, e.g. :

1. ROW :

followed by the name (or an abbreviation) of the variable to be entered. After input of the corresponding value and pressing R/S, the prompt for the next input will appear. Due to computation procedures, however, the system needs in some cases a certain time before it actually can accept the next input. The "ready for input" is indicated by the disappearance of the little PRGM-indicator from the display. For the convenience of the user, an audio signal is emitted as additional "ready" indicator whenever the time gap between two input prompts is unusually long.

~~~~~

Some programs need - for further computational procedure - to retain a variable's largest value entered. The system does this automatically during the normal data input mode. However, changes made while going through the correction routine are not considered. Therefore, to avoid any possible error, the following prompts are displayed after leaving the correction routine:

```
(Var. Name) <MAX> = xxx
CORRECTION ?
YES: 1, NO: 0
```

Specifying "0" will start the computation of the results, whereas "1" will enable the user to change the maximum value if this is necessary.

~~~~~

Results are presented in a format allowing display of both numeric and (abbreviated) textual information. For various reasons the user might, however, want to change this format e.g., to increase the number of digits displayed. There are basically two methods to accomplish this. We have left it to the user to find out which method will work with a given program.

Method 1 :

When the result of interest is displayed and the program stops automatically, press CLX.

If the numerical value of the result of interest is still in the display, press (f)FIX [n], with [n] being the number of decimals to be displayed. If the result of interest has disappeared use method 2.

In cases where the program has no automatic stop, press R/S to hold execution and proceed as above, considering that pressing R/S replaced pressing CLX.

Method 2 :

Refer to REGISTERS, STATUS, FLAGS to find out where the result of interest is stored (the symbol "[u]" labels stores used for various purposes). Recall it into the X-register (by pressing RCL nn) and set the format as in method 1.

2.6 Error Handling

If an error message occurs, the reason for it will almost certainly be an erroneous data entry. If the program has stored the original data set, the correction routine (accessed via "D") can be used to check the data set. Otherwise, the system should be re-initialized and the data re-entered.

2.7 Interruptions

The operation of a program can be stopped at any time by pressing "R/S". Pressing this key again restarts the program at the position where it was stopped. Pressing a key different from "R/S" will disrupt normal procedure and cause erroneous results. The only exception is the display of the menu, which can be stopped and then abandoned in order to select other parts of the program.

Table 2.1. PROGRAM DATA (For programs with primary data storage).

Progr. FB	# Reg. To Copy	# of Data Registers	For Maximum k		For	For
					SIZE = 100	k = 30
			k =	SIZE =	k =	SIZE =
1	185	(k*2)+16	58	132	42	076
3	192	(k*3)+19	36	127	27	109
6	194	(k*3)+16	36	127	28	106
7	205	(k*2)+33	40	113	33	093
11	150	(k)+21	148	169	79	051
12	154	(k)+21	144	165	79	051
24	160	(k*2)+16	71	158	42	076
25	201	(k*2)+16	51	118	42	076
30A	233	(k*2)+21	32	085	--	081

Note : "k" represents number of cases (= no. of rows)

Table 2.2 PROGRAM DATA (For programs without primary data storage).

Progr. FB	# Reg. To Copy	Data Registers	For Minimum Size SIZE =	# Free Reg.	For SIZE = 100 # Free Reg.
2	194	00 - 15	016	109	25
4	112	00 - 15	016	191	107
5	175	00 - 16	017	127	44
8	187	00 - 23	024	108	32
9	192	00 - 13	014	113	27
10	99	00 - 14	015	205	120
13	123	00 - 14	015	181	96
14	56	00 - 15	016	247	163
15	40	00 - 04	005	274	179
16	64	00 - 07	008	247	155
17	57	00 - 15	016	246	162
18	93	00 - 12	013	213	126
19	103	00 - 15	016	200	116
20	169	00 - 16	017	133	50
21	148	00 - 17	018	153	71
22	109	00 - 23	024	186	110
23	62	00 - 14	015	242	157
26	130	00 - 21	022	167	89
27	147	00 - 19	020	152	72
28	184	00 - 19	020	115	35
29	148	00 - 15	016	155	71
30B	233	00 - 26	027	59	---

Section 3
Program descriptions, user instructions,
listings and computation example

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Total number of magnetic cards needed for
Fishery Biology (FB) 1 to 30:

142^{a)}

a) Assuming that 1 program requiring 5 cards (i.e., FB 11, 12, 21, 24, 27 or 29) is stored on the last card, second track of FB 5, 6, 7, 10, 16, 19, 20, 22, 25, 26 and 30, or that 2 programs, requiring 2 or 3 cards (see above) are stored on the 2nd track of the last cards of 10 of the 11 programs using an odd number of tracks.

3.1: PROGRAM DESCRIPTION FB 1

Length-Weight Relationships

This program fits data to a length/weight relationship of the form

$$W = a.L^b \quad \dots 1)$$

where W is the weight and L is the length of an animal. The fit is obtained by means of a linear regression of the form

$$\log_{10} W = \log_{10} a + b \log_{10} L \quad \dots 2)$$

whose goodness of fit is estimated by r^2 .

To compensate for a systematic bias introduced by the transformation, the regression coefficient "a" is multiplied by a correction factor of the form

$$\text{Corr. F} = \exp (\text{SEE}^2/2) \quad \dots 3)$$

with SEE being the standard error of estimate of the regression. SEE is calculated from the formula

$$\text{SEE} = \log_e(10) \sqrt{\sum (\log_{10} W_i - \log_{10} \hat{W}_i)^2 / (N-2)} \quad \dots 4)$$

where the $\log_{10} W_i$'s are the values of the dependent variable and the $\log_{10} \hat{W}_i$'s are the corresponding predicted values calculated from the equation (Sprugel 1983).

Also, a condition factor (c.f.) is estimated by means of the expression

$$\text{c.f.} = W.100/L^3 \quad \dots 5)$$

Both expression (1) and the condition factor can be used to perform length-to-weight and weight-to-length conversions. When grams (live weight) and cm are used, the value of c.f. in most fishes will range between 0.5 and 2.0.

To test whether the values of b estimated via expression (2) differ significantly from the value of 3 used in expression (5) (isometric growth), a value of t is computed with each value of b which can be used in conjunction with a table of the t - distribution (d.f. = n - 2)

$$\hat{t} = \frac{b - 3}{\sqrt{1 - r^2}} \cdot \frac{S_x}{S_y} \cdot \sqrt{n - 2} \quad \dots 6)$$

as given in Sachs (1974, p. 339).

Operating Limits and Warnings

Values of b in equation (1) below 2.5 and 3.5 are questionable, and may reflect an entry error, or be based on too small a range of length and weight data.

An error message will appear after computation of b if $r^2 = 1$, as may occur when only few (2 or 3) rows have been entered.

FB 1 : LENGTH-WEIGHT RELATIONSHIPS

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM			* FB 1*
1.	DISPLAY OF MENU			MENU :
1.1	INPUT OF A SET OF DATA			DATA INP. : A
1.2	"SINGLE VALUE" - INPUT TO OBTAIN COND. FACT.			C.F. INP. <1> : B
1.3	ESTIMATE WT. FROM LENGTH (USING R.A. PAR.)			W. EST. <R.A.> : F
1.4	ESTIMATE LENGTH FROM WT. (USING R.A. PAR.)			L. EST. <R.A.> : G
1.5	ESTIMATE WT. FROM LENGTH (USING C.F.)			W. EST. (C.F.) : H
1.6	ESTIMATE LENGTH FROM WT. (USING C.F.)			L. EST. (C.F.) : I
1.7	}			MENU : C
1.8	} SEE GENERAL			INITIAL : c
1.9	} INSTRUCTIONS			REV. INP. : D
1.10	}			REV. RES. : E
2.	INPUT OPTION			
2.1	COMPUTE PARAMETERS OF LENGTH-WEIGHT RELATIONSHIPS (r^2 , a, b, c.f., t) [CONTINUE AT STEP 3]		A	* L/W REL.*
2.2	COMPUTE CONDITION FACTOR (C.F.) FROM SINGLE LENGTH-WEIGHT DATA PAIR		B	LENGTH ?
2.2.1	ENTER LENGTH	L	R/S	WEIGHT ?
2.2.2	ENTER WEIGHT (RESULT IS THE CORRESP. CONDITION FACTOR) ^{a)}	W	R/S	C.F. : (x)

a) NOTE : IF YOU WANT TO CALCULATE MORE CONDITION FACTORS, TWO OPTIONS ARE AVAILABLE :

i) "MEAN COND. FACT." : ALL L/W DATA PAIRS PREVIOUSLY ENTERED WILL BE INCLUDED IN THE COMPUTATION OF NEXT C.F.; TO COMPUTE THIS "MEAN C.F." PRESS "B" AND ENTER NEXT PAIR OF LENGTH AND WEIGHT.

ii) "SINGLE COND. FACT." : PRECEDING L/W DATA PAIRS ARE NOT INCLUDED IN THE COMPUTATION OF NEXT C.F.; TO USE ONLY NEW L/W DATA PAIRS PRESS "R/S" AND ENTER NEW LENGTH AND WEIGHT.

FB 1 : LENGTH-WEIGHT RELATIONSHIPS

USER INSTRUCTIONS (cont.)

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
PARAMETERS OF LENGTH-WEIGHT RELATION :				
3.	DATA INPUT			* L/W REL. *
				DATA INPUT :
				NO. OF ROWS ?
3.1	ENTER NO. OF ROWS	k	R/S	WEIGHT. F. ?
3.2	INDICATE IF YOU WANT TO USE ("1") OR NOT USE ("0") A WEIGHTING FACTOR	1 OR 0	R/S	YES : 1, NO : 0
3.3	ENTER FOR ROW 1, 2 ... k :			1. ROW :
3.3.1	LENGTH	L	R/S	LENGTH ?
3.3.2	WEIGHT	W	R/S	WEIGHT ?
3.3.3	WEIGHING FACTOR (IF SELECTED IN 3.2)	W.F.	R/S	WEIGHT. F ?
	NOTE: MAKE SURE YOU ENTER THE NEXT DATA SET AFTER THE "BEEP" :			2. (3 ... k) ROW :
	TO REVIEW PRECEDING INPUT, PRESS			:
4.	RESULTS		D	:
4.1	r^2			LAST INPUT
4.2	a			PLEASE WAIT
4.3	b			R^2 : (x)
4.4	VALUE FOR t-TEST			a : (x)
4.5	CONDITION FACTOR (C.F.)			b : (x)
4.6	OPTIONS :			T : (x)
	1. REVIEW RESULTS		E	C.F.: (x)
	2. REVIEW MENU		C (OR R/S)	(PROGR. STOP)
	3. RUN SUB-PROGRAMS		F, G, H OR I	
5.	SUB-PROGRAMS			
5.1	TO COMPUTE WEIGHT ESTIMATES FOR ANY GIVEN LENGTH USE:			
5.1.1	OPTION			
5.1.1.1	PARAMETERS OF L/W REL. (a, b), PRESS		F	LENGTH ?
5.1.1.2	CONDITION FACTOR (C.F.), PRESS		H	LENGTH ?
5.1.2	AND ENTER LENGTH (RESULT : WEIGHT ESTIMATE)	L	R/S	<W> : (x)
				:
				NEXT LENGTH ?

FB 1 : LENGTH-WEIGHT RELATIONSHIPS

USER INSTRUCTIONS (cont.)

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
5.1.3.	OPTIONS :			
5.1.3.1	ENTER NEXT LENGTH VALUES	L	R/S	<W>: (x)
5.1.3.2	SWITCH TO A DIFFERENT SUB-PROGRAM		F / G / H / I	
5.2	TO COMPUTE LENGTH ESTIMATES FOR ANY GIVEN WEIGHT ^{a)} , USE			
5.2.1	OPTIONS :			
5.2.1.1	PARAMETERS OF L/W REL. (a,b), PRESS		G	WEIGHT ?
5.2.1.2	CONDITION FACTOR (C.F.), PRESS		I	WEIGHT ?
5.2.2	AND ENTER WEIGHT (RESULT : LENGTH ESTIMATE)	W	R/S	<L> : (x) : NEXT WEIGHT ?
5.2.3	OPTIONS :			
5.2.3.1	ENTER NEXT WEIGHT	W	R/S	<L>: (x)
5.2.3.2	SWITCH TO A DIFFERENT SUB-PROGRAM		F,G,H,I	
6	FOR A NEW SET OF DATA, INITIALIZE		f c	* FB 1 *

a) NOTE: PREDICTING L FROM W BASED ON A "PREDICTIVE" REGRESSION OF LOG W ON LOG L IS IN PRINCIPLE INAPPROPRIATE. HOWEVER, THE HIGH CORRELATIONS USUALLY OCCURRING IN L/W REL. MAKE THE DISTINCTION BETWEEN "PREDICTIVE" AND "FUNCTIONAL" REGRESSIONS LARGELY IRRELEVANT (BUT SEE RICKER 1973).

REGISTERS, STATUS, FLAGS

PROGR. NAME: FB 1 (Length-Weight Relationship)

STATUS : REG. (PROGR.): 186
 SIZE (MIN.) : (k*2)+16 SIZE (MAX.): 134

FLAGS : 5-10

ASSIGNMENTS:

A: GENERAL COMMANDS

INITIALIZE : (f)c
REVIEW RESULTS : E
RECALL MENU : C
REVIEW INPUT : D

B: SPECIAL COMMANDS

INPUT DATA SET : A
INPUT SINGLE DATA PAIR: B
WEIGHT EST. (REGR. P.): F
LENGTH EST. (REGR. P.): G
WEIGHT EST. (COND. F.): H
LENGTH EST. (COND. F.): I

REGISTERS :

SUB-

PROGR.:	A	B	F	G	H	I
00 :	[u]	-	[u]	[u]	[u]	[u]
01 :	T	-	[u]	[u]	[u]	[u]
02 :	c.f.	c.f.	[u]	[u]	[u]	[u]
03 :	r ²		[u]	[u]	[u]	[u]
04 :	a		[u]	[u]	[u]	[u]
05 :	b		[u]	[u]	[u]	[u]
06 :	-		LENGTH	WEIGHT	LENGTH	WEIGHT
07 :	-		EST. W.	EST. L.	EST. W.	EST. L.
08 :	[u]					
09 :	[u]					
10 :	[u]					
11 :	[u]					
12 :	[u]					
13 :	[u]					
14 :	[u]					
15 :	[u]					
16 :	log L(1)					
17 :	log W(1)					
	.					
	.					
	log L(k)					
	log W(k)					

NOTE: "k" REPRESENTS NUMBER OF CASES (= NO. OF ROWS)

Program Listing

(FB 1)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01*LBL "FB 1"		57 "P<C.F"		113 STO 05		169 2		225 RCL 13	
02*LBL C		58*LBL 01		114 RDN		170 "W"		226 RCL 12	
03 CF 21		59 "F.>."		115 X<> 03		171 XEQ "P"		227 X+2	
04 BEEP		60 ARCL X		116 STO 04		172 FC? 10		228 RCL 15	
05 " * FB 1 *"		61*LBL 05		117 FS? 06		173 GTO 01		229 /	
06 XEQ "Q"		62 AVIEW		118 GTO 02		174 1		230 -	
07 SF 27		63 PSE		119 ISG 00		175 "W.F."		231 /	
08 CF 06		64 PSE		120 GTO 01		176 XEQ "P"		232 RCL 11	
09 CF 08		65 RTN		121 SF 09		177*LBL 01		233 RCL 10	
10 CF 09		66*LBL E		122 GTO 02		178 "CORRECTION ?"		234 X+2	
11 CF 10		67 FS? 08		123*LBL 01		179 XEQ 14		235 RCL 15	
12 SREG 10		68 GTO "0"		124 XEQ 07		180 X=0?		236 /	
13 CLRG		69 GTO "2"		125*LBL 02		181 GTO 01		237 -	
14*LBL C		70*LBL B		126 RCL 04		182 DSE 00		238 ST/ 05	
15 "MENU :"		71 XEQ "W"		127 LOG		183*LBL "Y"		239 /	
16 XEQ 05		72 RDN		128 XEQ 01		184 XEQ 07		240 STO 03	
17 "DATA INP.: A"		73 LOG		129 ISG 09		185 XEQ "W"		241 RCL 12	
18 XEQ 05		74 X<>Y		130 ST+ 10		186 STO 01		242 RCL 05	
19 "C.F. INP. <1>:"		75 LOG		131 X<>Y		187 RDN		243 RCL 10	
20 "FB"		76 S+		132 ST+ 11		188 STO 02		244 *	
21 XEQ 05		77 XEQ 10		133 X<>Y		189 X<>Y		245 -	
22 "F"		78 "C.F. :"		134 RCL 05		190 STO 03		246 RCL 15	
23 XEQ 03		79 ARCL X		135 LOG		191 ISG 00		247 /	
24 XEQ 02		80 PROMPT		136 ST* Y		192*LBL 01		248 STO 04	
25 "G"		81 CLS		137 XEQ 01		193 FC? 06		249 RCL 00	
26 XEQ 01		82 GTO B		138 ST+ 12		194 XEQ 07		250 INT	
27 XEQ 02		83*LBL A		139 RDN		195 GTO "R"		251 1	
28 "H"		84 "*/W REL.*"		140 ST+ 13		196*LBL 14		252 -	
29 XEQ 03		85 XEQ "Q"		141 X<>Y		197 AVIEW		253 STO 00	
30 XEQ 04		86 "DATA INPUT"		142 ST+ 14		198 TONE 7		254 XEQ "U"	
31 "I"		87 AVIEW		143 GTO 02		199 PSE		255*LBL "K"	
32 XEQ 01		88 PSE		144*LBL 01		200 "YES: 1, NO: 0"		256 RCL IND 09	
33 XEQ 04		89 "NO. OF ROWS ?"		145 STO IND 09		201 PROMPT		257 RCL 05	
34 "MENU : C"		90 PROMPT		146 ENTER↑		202 RTN		258 *	
35 XEQ 05		91 STO 00		147 ST* Y		203*LBL 07		259 RCL 04	
36 "INIT.: C"		92 XEQ "U"		148 RCL 06		204 FIX 0		260 +	
37 XEQ 05		93 RCL 00		149 ST* Y		205 CLA		261 ISG 09	
38 "REV. INPUT : D"		94 3		150 ST* Z		206 ARCL 00		262 RCL IND 09	
39 XEQ 05		95 10+X		151 RDN		207 "F."		263 X<>Y	
40 "REV. RES.: E"		96 /		152 RTN		208*LBL 05		264 -	
41 PROMPT		97 1		153*LBL 02		209 "F ROW :"		265 X+2	
42 GTO A		98 +		154 FS? 06		210 AVIEW		266 ST+ 00	
43*LBL 01		99 STO 00		155 GTO 04		211 PSE		267 ISG 09	
44 ASTO X		100 "WEIGHT. F. ?"		156 ISG 09		212 RTN		268 GTO "K"	
45 "L"		101 XEQ 14		157 X<>Y		213*LBL 04		269 RCL 00	
46 GTO 01		102 X=0?		158 FC? 09		214 "PLEASE WAIT"		270 RCL 00	
47*LBL 03		103 SF 10		159 GTO "R"		215 AVIEW		271 2	
48 ASTO X		104 GTO "Y"		160 SF 06		216 RCL 14		272 -	
49 "W"		105*LBL "R"		161*LBL D		217 RCL 10		273 /	
50*LBL 01		106 FC? 06		162 "LAST INPUT :"		218 RCL 12		274 SORT	
51 "F.-EST.		107 XEQ "W"		163 AVIEW		219 *		275 10	
52 RTN		108 X<> 01		164 PSE		220 RCL 15		276 LN	
53*LBL 02		109 STO 06		165 FIX 3		221 /		277 *	
54 "F(R.A"		110 ST+ 15		166 3		222 -		278 X+2	
55 GTO 01		111 RDN		167 "L"		223 STO 05		279 2	
56*LBL 04		112 X<> 02		168 XEQ "P"		224 X+2		280 /	

Program Listing

(FB 1 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
281	E1X	337	RTN	393	SF 05	449	*	505	9
282	RCL 04	338	CF 05	394	TONE 7	450	GTO 03	506	X<>Y
283	101X	339	CF 07	395	GTO 0	451	LBL 01	507	ARCL IND X
284	*	340	FIX 3	396	LBL F	452	RCL 04	508	7
285	STO 04	341	FS? 55	397	SF 10	453	/	509	XEQ "X"
286	RCL 11	342	GTO 01	398	SF 09	454	RCL 05	510	CF 21
287	RCL 10	343	BEEP	399	GTO 08	455	1/X	511	GTO "N"
288	XEQ 01	344	LBL "2"	400	LBL G	456	Y1X	512	LBL 13
289	RCL 13	345	FS? 05	401	CF 10	457	GTO 03	513	8
290	RCL 12	346	SF 07	402	SF 01	458	LBL 02	514	FC? 10
291	XEQ 01	347	"R+2"	403	LBL 08	459	FC? 10	515	9
292	GTO 02	348	3	404	SF 21	460	GTO 01	516	8
293	LBL 01	349	XEQ "P"	405	ADV	461	3	517	X<>Y
294	X+2	350	"a"	406	"REGR"	462	Y1X	518	ARCL IND X
295	RCL 15	351	4	407	GTO 06	463	RCL 02	519	RTN
296	/	352	XEQ "P"	408	LBL H	464	*	520	LBL "P"
297	-	353	"b"	409	SF 10	465	X<>Y	521	"H : "
298	RCL 15	354	5	410	CF 09	466	/	522	ARCL IND X
299	1	355	XEQ "P"	411	GTO 09	467	GTO 03	523	AVIEW
300	-	356	"T"	412	LBL I	468	LBL 01	524	PSE
301	/	357	1	413	CF 10	469	*	525	PSE
302	SORT	358	XEQ "P"	414	CF 11	470	RCL 02	526	RTN
303	RTN	359	"C.F."	415	LBL 09	471	/	527	LBL "X"
304	LBL 02	360	2	416	SF 21	472	3	528	"H : "
305	/	361	XEQ "P"	417	ADV	473	1/X	529	ACA
306	RCL 05	362	FC? 07	418	"C.F."	474	Y1X	530	RCL IND X
307	3	363	STOP	419	LBL 06	475	LBL 03	531	ACX
308	-	364	GTO 03	420	CF 21	476	STO 07	532	PRBUF
309	ABS	365	LBL 01	421	SF 08	477	FIX 2	533	RTN
310	1	366	XEQ "S"	422	"H. GIVES :"	478	FS? 55	534	LBL "Q"
311	RCL 03	367	SF 21	423	XEQ "T"	479	GTO 03	535	AVIEW
312	-	368	ADV	424	PSE	480	LBL "0"	536	PSE
313	SORT	369	SF 13	425	"LENGTH"	481	"<"	537	FC? 55
314	/	370	3	426	ASTO 06	482	FS? 10	538	RTN
315	*	371	"R+2"	427	"WEIGHT"	483	GTO 01	539	SF 21
316	RCL 15	372	XEQ "X"	428	ASTO 09	484	"HL"	540	ADV
317	2	373	4	429	"ENTER :"	485	GTO 02	541	ADV
318	-	374	"a"	430	AVIEW	486	LBL 01	542	SF 12
319	SORT	375	XEQ 01	431	PSE	487	"HW"	543	GTO 01
320	*	376	5	432	CLA	488	LBL 02	544	LBL "S"
321	STO 01	377	"b"	433	GTO 01	489	">"	545	"RESULTS :"
322	LBL 10	378	XEQ 01	434	LBL "N"	490	7	546	BEEP
323	RCL 12	379	ADV	435	"NEXT "	491	XEQ "P"	547	LBL "T"
324	RCL 15	380	"T "	436	LBL 01	492	PSE	548	AVIEW
325	/	381	1	437	XEQ 13	493	GTO "N"	549	FC? 55
326	2	382	XEQ "P"	438	"F?"	494	LBL 03	550	RTN
327	+	383	"C.F."	439	100	495	SF 21	551	SF 21
328	RCL 10	384	2	440	PROMPT	496	ADV	552	ADV
329	RCL 15	385	XEQ "P"	441	STO 06	497	"FOR "	553	LBL 01
330	/	386	CF 13	442	FC? 09	498	XEQ 13	554	ACA
331	3	387	CF 21	443	GTO 02	499	6	555	PRBUF
332	*	388	GTO 07	444	FC? 10	500	XEQ "X"	556	CF 12
333	-	389	LBL 01	445	GTO 01	501	"EST. "	557	CF 21
334	101X	390	"H "	446	RCL 05	502	9	558	RTN
335	STO 02	391	GTO "X"	447	Y1X	503	FC? 10	559	LBL "U"
336	FC? 06	392	LBL 03	448	RCL 04	504	8	560	RCL 00

Program Listing

(FB 1 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
561	2								
562	*								
563	15								
564	+								
565	3								
566	101%								
567	/								
568	16								
569	+								
570	STO 09								
571	RTN								
572	*LBL "W"								
573	TONE 7								
574	"LENGTH ?"								
575	PROMPT								
576	"WEIGHT ?"								
577	PROMPT								
578	FS? 10								
579	GTO 01								
580	1								
581	RTN								
582	*LBL 01								
583	"WEIGHT. F. ?"								

EXAMPLE 3.1

(See also page 8 in manual)

Data from Appendix I,
Tab. 2.1

* FB 1 *

L/W REL.

RESULTS :

rt2 : 0.993

a : 0.011

b : 3.058

t : 0.821

c.f. : 1.251

C.F. GIVES :

FOR WEIGHT : 5.00
EST. LENGTH : 7.46

FOR WEIGHT : 10.00
EST. LENGTH : 9.36

FOR WEIGHT : 20.00
EST. LENGTH : 11.74

FOR WEIGHT : 100.00
EST. LENGTH : 19.87

REGR. GIVES :

FOR WEIGHT : 5.00
EST. LENGTH : 7.46

FOR WEIGHT : 10.00
EST. LENGTH : 9.36

FOR WEIGHT : 20.00
EST. LENGTH : 11.74

FOR WEIGHT : 100.00
EST. LENGTH : 19.87

3.2: PROGRAM DESCRIPTION FB 2

Gear Selection

This program is (i) an implementation of the Baranov/Holt method to estimate the selectivity of a pair of gill nets, each of which is assumed to have a symmetrical (normal) selection curve with equal variance.

A linear regression is used which has the form

$$Y = a + bL \quad \dots 1)$$

where

$$Y = \ln (C_B/C_A)$$

where C_A is the catch by length class of a gill net with mesh size A, C_B is the corresponding catch for B, and where L corresponds to the class midlength, with $A < B$. The optimum lengths (L_A, L_B) are obtained from

$$L_A = (-2a - bA)/(b(A + B)) \quad \dots 2)$$

and correspondingly for L_B , while the standard deviation of the selection curves is given by

$$s.d. = \sqrt{(2a(A-B)/(b^2(A+B)))} \quad \dots 3)$$

Once L_A, L_B and s.d. have been estimated, the probability of capture at a given length L is given by

$$P_A = \exp ((L - L_A)^2/(-2 s.d.^2)) \quad \dots 4)$$

and correspondingly for L_B . The possibility is offered to plot $\ln (C_B/C_A)$ on $\ln (\text{length})$, rather than on length itself. This results in asymmetrical selection curves.

This program (ii) also estimates mean length at first capture (L_c) based on data from a trawl selection experiment, using the equation

$$L_c = L_{n+1} - \sum P_i \quad \dots 5)$$

where L_n is the lower class limit of the highest length class considered, while $\sum P_i$ is the sum of the fractions retained. Both parts of this program are based on Gulland (1969, p. 84-95); the latter has been modified such that length class width may differ from unity.

Operating Limits and Warnings

The assumptions used in the derivation of the equations above must be considered when applying the methods, and the original literature must be considered for possible sources of problems. In both methods, classes with zero catches for both mesh sizes must not be included.

FB 2: GEAR SELECTION

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM			* FB 2*
1.	DISPLAY OF MENU			MENU
1.1	TRAWL SELECTION			TRAWL S: A
1.2	GILL NET SELECTION			GILLNET S: B
1.3	}			MENU: C
1.4	} SEE GENERAL			INIT.: c
1.5	} INTRODUCTION			REV. INPUT: D
1.6	}			REV. RES.: E
2.	<u>TRAWL SELECTION</u>		A	* TRAWL *
2.1	ENTER:			DATA INPUT:
				NO. OF ROWS ?
2.1.1	NUMBER OF ROWS	k	R/S	L <MIN> ?
2.1.2	<u>LOWER CLASS LIMIT OF</u> <u>SMALLEST LENGTH CLASS</u> ^{a)}	L MIN	R/S	CLASS WIDTH ?
2.1.3	CLASS WIDTH	h	R/S	L. CL.: (1)
				:
2.2	ENTER FOR LENGTH CLASS 1, 2 ... k : b), c)			N >COVER< ?
2.2.1	NUMBER OF FISH IN COVER	N COV 1, 2 ... k	R/S	N >CODEND< ?
2.2.2	NUMBER OF FISH IN CODEND	N COD 1, 2 ... k	R/S	L. CL.: (2, 3 ... k)
2.3	DISPLAY OF RESULT MEAN SIZE AT FIRST CAPTURE (L _c)			(RESULT) L<c>: (x)
3.	<u>GILL NET SELECTION</u>		B	* GILLNET *
3.1	<u>TYPE OF SELECTION CURVE:</u> ENTER:			SELECT CURVE:
				OPTION:
				SYMMETR: 1
				ASYMMETR: 2
	1 (=SYMMETR. SEL. C.) OR 2 (=ASYMMETR. SEL. C.)	1 OR 2	R/S	MESH SIZES:
3.2	ENTER MESH SIZES:			SMALL <A> ?
				LARGE ?
3.2.1	SMALLER MESH SIZE (=GILLNET "A")	M _A	R/S	
3.2.2	LARGER MESH SIZE (=GILLNET "B")	M _B	R/S	DATA INPUT:

FB 2: GEAR SELECTION

USER INSTRUCTIONS (cont.)

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
3.3	ENTER:			NO. OF ROWS ?
3.3.1	NUMBER OF ROWS	k	R/S	L <MIN> ?
3.3.2	MIDLENGTH OF SMALLEST LENGTH CLASS ^{a)}	L MIN	R/S	CLASS WIDTH ?
3.3.3	CLASS WIDTH	h	R/S	L. CL.: (1) :
3.4	ENTER FOR LENGTH CLASS 1, 2 ... k : ^{d),c)}			N <A> ?
3.4.1	NUMBER OF FISH IN GILLNET A	N _A	R/S	N ?
3.4.2	NUMBER OF FISH IN GILLNET B	N _B	R/S	L. CL.: (2, 3 .. k) : : (RESULTS) :
3.5	DISPLAY OF RESULTS			
3.5.1	r ²			R^2 : (x)
3.5.2	a			a : (x)
3.5.3	b			b : (x)
3.5.4	STANDARD DEVIATION ^{e)}			S.D.: (x)
3.5.5	OPTIMUM LENGTH (GILLNET "A")			L<A>: (x)
3.5.6	OPTIMUM LENGTH (GILLNET "B")			L: (x) (PROGR. STOP) :
3.6	OPTIONS :			
3.6.1	REVIEW RESULTS		E	(RESULTS)
3.6.2	COMPUTE P-ESTIMATES		R/S	P-ESTIMATES SEL. MESH SIZE:
3.7	TO OBTAIN PROBABILITIES OF CAPTURE BY LENGTH, ENTER OPTION :			<A>: 1, : 2
3.7.1	FOR MESH SIZE "A"	1	R/S	:
3.7.2	FOR MESH SIZE "B"	2	R/S	:
3.8	ENTER			ENTER
3.8.1	LENGTH	L	R/S	LENGTH ? (RESULT)
3.8.2	DISPLAY OF RESULT:			
3.8.2.1	PROBABILITY P(A) (IF OPTION 1 SELECTED) OR			P <A>: (x)

FB 2: GEAR SELECTION

USER INSTRUCTIONS (cont.)

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
3.8.2.2	PROBABILITY P(B) (IF OPTION 2 SELECTED)			P : (x)
3.9	OPTIONS :			NEXT LENGTH ?
3.9.1	NEXT LENGTH INPUT, SAME MESH SIZE	L	R/S	(RESULT)
3.9.2	SWITCH TO OTHER MESH SIZE OPTION, DO AND GO TO 3.6.2	(NO INPUT!)	R/S	P-ESTIMATES
4.	FOR A NEW CASE, INITIALIZE		fc	* FB 2 *

NOTES :

a) SMALLEST LENGTH CLASS IS DEFINED AS THE FIRST TO CONTAIN NON-ZERO CATCHES.

b) IF LENGTH CLASSES WITH ZERO CATCHES OCCUR IN BOTH THE CODEND AND THE COVER, PRESS "R/S" UPON REACHING STEP 2.2.1 AND PROCEED WITH DATA PAIR FOR NEXT LENGTH CLASS.

c) OPTION: REVIEW PRECEDING INPUT; TO DO SO, PRESS "D" (SEE GENERAL INSTRUCTIONS).

d) IF LENGTH CLASSES WITH ZERO CATCHES OCCUR IN EITHER ONE OR BOTH GILLNETS, PRESS "R/S" UPON REACHING STEP 3.4.1 AND PROCEED WITH DATA PAIR FOR NEXT LENGTH CLASS.

e) IF ASYMMETRIC SEL. CURVE HAS BEEN SELECTED, "S.D." IS EXPRESSED IN LOG_e UNITS.

REGISTERS, STATUS, FLAGS

PROGR. NAME: FB 2 (Gear Selection)

STATUS : REG. (PROGR.): 195
SIZE (MIN.) : 016 SIZE (MAX.): -

FLAGS : 0, 5 - 10

ASSIGNMENTS:

A: GENERAL COMMANDS

B: SPECIAL COMMANDS

INITIALIZE : (f)c
REVIEW RESULTS : E
RECALL MENU : C
REVIEW INPUT : D

TRAWL SELECTION : A
GILL NET SELECTION : B

REGISTERS :

SUB-

PROGR.:	A	B
00 :	[u]	[u]
01 :	[u]	L<A>
02 :	[u]	L
03 :	[u]	r ²
04 :	[u]	a
05 :	[u]	b
06 :	[u]	s.d.
07 :	[u]	[u]
08 :	L<c>	[u]
09 :	[u]	P<A/B>
10 :		[u]
11 :		[u]
12 :		[u]
13 :		[u]
14 :		[u]
15 :		[u]

Program Listing

(FB 2)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01	LBL "FB 2"	57	ASTO 09	113	3	169	"<A>"	225	RTN
02	LBL C	58	AVIEW	114	10+X	170	LBL 02	226	LBL 07
03	CF 21	59	PSE	115	/	171	XEQ "P"	227	FIX 1
04	BEEP	60	PSE	116	1	172	5	228	"L. CL. : "
05	" * FB 2 *"	61	"ASYMMETR. : 2"	117	+	173	FS? 10	229	ARCL 09
06	XEQ "Q"	62	PROMPT	118	STO 00	174	GTO 01	230	AVIEW
07	SF 27	63	2	119	"<MIN> ?"	175	"<C.E.>"	231	PSE
08	10	64	X=Y?	120	PROMPT	176	GTO 02	232	RTN
09	LBL "A"	65	SF 00	121	STO 02	177	LBL 01	233	LBL 05
10	CF IND X	66	CLA	122	STO 09	178	""	234	"PLEASE WAIT"
11	DSE X	67	FS? 00	123	"CLASS WIDTH?"	179	LBL 02	235	AVIEW
12	GTO "M"	68	"A"	124	PROMPT	180	LBL 02	236	RCL 14
13	CF 00	69	ARCL 09	125	STO 03	181	XEQ "P"	237	RCL 10
14	SREG 10	70	"R. SEL. CURVE"	126	GTO "Y"	182	"CORRECTION ?"	238	RCL 12
15	CLRG	71	FC? 55	127	LBL "P"	183	XEQ 14	239	*
16	LBL C	72	GTO 01	128	FC? 06	184	X=0?	240	RCL 15
17	"MENU : "	73	SF 21	129	XEQ "W"	185	GTO 01	241	/
18	AVIEW	74	ADV	130	X<> 05	186	RCL 03	242	-
19	PSE	75	ADV	131	STO 07	187	ST- 09	243	STO 05
20	PSE	76	ACA	132	X<>Y	188	LBL "Y"	244	X+2
21	"TRAWL S. : A"	77	PRBUF	133	X<> 04	189	XEQ 07	245	RCL 13
22	AVIEW	78	CF 21	134	STO 06	190	XEQ "W"	246	RCL 12
23	PSE	79	LBL 01	135	LBL "L"	191	STO 05	247	X+2
24	PSE	80	"MESH SIZES : "	136	FS? 06	192	X<>Y	248	RCL 15
25	"GILLNET S. : B"	81	XEQ "T"	137	GTO 02	193	STO 04	249	/
26	AVIEW	82	PSE	138	RCL 03	194	RCL 03	250	-
27	PSE	83	FIX 2	139	ST+ 09	195	ST+ 09	251	/
28	PSE	84	1	140	ISG 00	196	ISG 00	252	RCL 11
29	"MENU : C"	85	"SMALL <A>"	141	GTO 01	197	LBL 01	253	RCL 10
30	AVIEW	86	XEQ 02	142	SF 09	198	FC? 06	254	X+2
31	PSE	87	8	143	GTO 02	199	XEQ 07	255	RCL 15
32	"INIT. : c"	88	"LARGE "	144	LBL 01	200	GTO "P"	256	/
33	AVIEW	89	XEQ 02	145	XEQ 07	201	LBL 04	257	-
34	PSE	90	GTO 01	146	LBL 02	202	RCL 00	258	ST/ 05
35	"REV. INPUT : D"	91	LBL 02	147	FC?C 05	203	INT	259	/
36	AVIEW	92	ASTO 09	148	XEQ "U"	204	1	260	STO 03
37	PSE	93	"- ?"	149	FC? 06	205	-	261	RCL 12
38	"REV. RES. : E"	94	PROMPT	150	GTO 01	206	RCL 01	262	RCL 05
39	PROMPT	95	STO IND Y	151	FC? 10	207	-	263	RCL 10
40	GTO C	96	X<>Y	152	GTO 04	208	RCL 03	264	*
41	LBL E	97	CLA	153	GTO 05	209	*	265	-
42	FS? 08	98	ARCL 09	154	LBL 01	210	RCL 02	266	RCL 15
43	GTO "0"	99	SF 21	155	FC? 09	211	+	267	/
44	GTO "Z"	100	FS? 55	156	GTO "R"	212	STO 08	268	STO 04
45	LBL B	101	XEQ "X"	157	SF 06	213	FIX 2	269	RCL 08
46	SF 10	102	CF 21	158	LBL D	214	"L<c> : "	270	FS? 00
47	"* GILLNET *"	103	RTN	159	FIX 0	215	ARCL X	271	LN
48	XEQ "Q"	104	LBL A	160	"LAST INPUT : "	216	XEQ "T"	272	STO 09
49	"SELECT. CURVE : "	105	"* TRAWL *"	161	AVIEW	217	STOP	273	STO 02
50	AVIEW	106	XEQ "Q"	162	PSE	218	GTO C	274	RCL 01
51	PSE	107	LBL 01	163	4	219	LBL 14	275	FS? 00
52	PSE	108	"DATA INPUT : "	164	FS? 10	220	AVIEW	276	LN
53	"OPTION : "	109	AVIEW	165	GTO 01	221	TONE 7	277	STO 06
54	AVIEW	110	PSE	166	"<COV.>"	222	PSE	278	STO 01
55	PSE	111	"NO. OF ROWS ?"	167	GTO 02	223	"YES: 1, NO: 0"	279	+
56	"SYMMETR. : 1"	112	PROMPT	168	LBL 01	224	PROMPT	280	RCL 05

Program Listing

(FB 2 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
281 *		337 XEQ "P"		393 AVIEW		449 "P(B)"		505 RTN	
282 1/X		338 "L(B)"		394 PSE		450 9		506+LBL 01	
283 RCL 04		339 2		395 PSE		451 XEQ "X"		507 "N >CODEND< ?"	
284 2		340 XEQ "P"		396 CLA		452 CF 21		508 PROMPT	
285 *		341 FC? 07		397 GTO 01		453 GTO "N"		509 RTN	
286 STO 06		342 STOP		398+LBL "N"		454+LBL "P"		510+LBL 02	
287 CHS		343 GTO 03		399 "NEXT "		455 "F : "		511 "N(A) ?"	
288 *		344+LBL 01		400+LBL 01		456 ARCL IND X		512 PROMPT	
289 ST+ 01		345 XEQ "S"		401 CF 22		457 AVIEW		513 FS? 22	
290 ST+ 02		346 SF 21		402 "PLENGTH?"		458 PSE		514 GTO 01	
291 FC? 00		347 ADV		403 PROMPT		459 PSE		515 SF 05	
292 GTO 01		348 SF 13		404 FC? 22		460 RTN		516 GTO "L"	
293 RCL 01		349 3		405 GTO "K"		461+LBL "X"		517+LBL 01	
294 E+X		350 "R+2 "		406 STO 08		462 "F : "		518 "N(B) ?"	
295 STO 01		351 XEQ "X"		407 SF 08		463 ACA		519 PROMPT	
296 RCL 02		352 4		408 1		464 RCL IND X		520 RTN	
297 E+X		353 "a"		409 FS? 10		465 ACX		521+LBL "U"	
298 STO 02		354 XEQ 01		410 2		466 PRBUF		522 FS? 10	
299+LBL 01		355 5		411 1		467 RTN		523 GTO 01	
300 RCL 00		356 "b"		412 X<>Y		468+LBL "0"		524 RCL 07	
301 RCL 09		357 XEQ 01		413 RCL IND X		469 AVIEW		525 ENTER+	
302 -		358 6		414 FS? 00		470 PSE		526 ENTER+	
303 RCL 06		359 "S.D."		415 LN		471 FC? 55		527 RCL 06	
304 *		360 XEQ "X"		416 CHS		472 RTN		528 +	
305 RCL 08		361 CF 13		417 RCL 08		473 SF 21		529 /	
306 RCL 09		362 ADV		418 FS? 00		474 ADV		530 ST+ 01	
307 +		363 1		419 LN		475 ADV		531 RTN	
308 RCL 05		364 "L(A)"		420 +		476 SF 12		532+LBL 01	
309 X+2		365 XEQ "P"		421 X+2		477 GTO 01		533 RCL 07	
310 *		366 "L(B)"		422 RCL 06		478+LBL "S"		534 RCL 06	
311 /		367 2		423 X+2		479 "RESULTS :"		535 /	
312 SORT		368 XEQ "P"		424 2		480 BEEP		536 LN	
313 STO 06		369 CF 21		425 *		481+LBL "T"		537 RCL 02	
314 CF 05		370 GTO 03		426 CHS		482 AVIEW		538 FS? 00	
315 CF 07		371+LBL 01		427 /		483 FC? 55		539 LN	
316 FIX 3		372 "F : "		428 E+X		484 RTN		540 C+	
317 FS? 55		373 GTO "X"		429 STO 09		485 SF 21		541 RCL 03	
318 GTO 01		374+LBL 03		430 FIX 3		486 ADV		542 ST+ 02	
319 BEEP		375 SF 05		431 FS? 55		487+LBL 01		543 .END.	
320+LBL "Z"		376 TONE 7		432 GTO 01		488 ACA			
321 FS? 05		377+LBL "K"		433+LBL "0"		489 PRBUF			
322 SF 07		378 CF 10		434 "P(A)"		490 CF 12			
323 "R+2"		379 "P-ESTIMATES"		435 FS? 10		491 CF 21			
324 3		380 XEQ "T"		436 "P(B)"		492 RTN			
325 XEQ "P"		381 PSE		437 9		493+LBL "W"			
326 "a"		382 "SEL. MESH5IZ"		438 XEQ "P"		494 CF 22			
327 4		383 "F-E"		439 PSE		495 TONE 7			
328 XEQ "P"		384 AVIEW		440 GTO "H"		496 FS? 10			
329 "b"		385 PSE		441+LBL 01		497 GTO 02			
330 5		386 PSE		442 SF 21		498 "N >COVER< ?"			
331 XEQ "P"		387 "<A>: 1, : 2"		443 ADV		499 PROMPT			
332 "S.D."		388 PROMPT		444 "FOR LENGTH"		500 FS? 22			
333 6		389 2		445 8		501 GTO 01			
334 XEQ "P"		390 X=Y?		446 XEQ "X"		502 0			
335 "L(A)"		391 SF 10		447 "P(A)"		503 ENTER+			
336 1		392 "ENTER :"		448 FS? 10		504 1			

EXAMPLE 3.2

(See also pages 19, 21, and 22 in manual)

Data from Appendix I,
Tab. 3.1

* FB 2 *

* TRAWL *

L(c) : 13.88

Data from Appendix I,
Tab. 3.3

* FB 2 *

* GILLNET *

SYMMETR. SEL. CURVE

MESH SIZES :
SMALL : 8.10
LARGE : 9.10

RESULTS :

r² : 0.996
a : -39.881
b : 1.881
s.d. : 1.195

L(A) : 20.818
L(B) : 23.388

P-ESTIMATES

FOR LENGTH : 19.000
P(A) : 0.314

FOR LENGTH : 20.000
P(A) : 0.791

FOR LENGTH : 21.000
P(A) : 0.988

P-ESTIMATES

FOR LENGTH : 19.000
P(B) : 0.001

FOR LENGTH : 20.000
P(B) : 0.018

FOR LENGTH : 21.000
P(B) : 0.136

Data from Appendix I,
Tab. 3.4

* FB 2 *

* GILLNET *

ASYMMETR. SEL. CURVE

MESH SIZES :
SMALL : 7.60
LARGE : 10.20

RESULTS :

r² : 0.941
a : -36.024
b : 11.224
s.d. : 0.197

L(A) : 19.936
L(B) : 30.774

P-ESTIMATES

FOR LENGTH : 17.500
P(A) : 0.883

FOR LENGTH : 19.500
P(A) : 0.994

FOR LENGTH : 21.500
P(A) : 0.929

P-ESTIMATES

FOR LENGTH : 17.500
P(B) : 0.016

FOR LENGTH : 19.500
P(B) : 0.068

FOR LENGTH : 21.500
P(B) : 0.190

3.3: PROGRAM DESCRIPTION FB 3

Von Bertalanffy Plot

The generalized von Bertalanffy Growth Formula has for length the form

$$L_t = L_{(\infty)} (1 - e^{-KD(t-t_o)})^{1/D} \quad \dots 1)$$

and for weight the form

$$W_t = W_{(\infty)} (1 - e^{-KD(t-t_o)})^{b/D} \quad \dots 2)$$

where b is the exponent of the length weight relationship. Equation (1) can be rewritten as

$$\ln (1 - [L_t^D / L_{(\infty)}^D]) = KDt_o - KDt \quad \dots 3)$$

which has the form of a linear regression, where

$$\ln (1 - [L_t^D / L_{(\infty)}^D]) = y,$$

$t = x$ and $KDt_o = a$. Thus, given a preliminary estimate of $L_{(\infty)}$ (estimated automatically by the program, from $L_{\max}/0.99$) and a value of D, the values of K and t_o are easily estimated and the preliminary value of $L_{(\infty)}$ improved iteratively, until a maximum value of r^2 is reached. The method is similar for weight growth, except that values of $W^{1/b}$ are used instead of the weights themselves.

Weighting factors other than n may be used; the inverse (1/s.e.) of the standard error (s.e.) of the mean size in each age group is, for example, a very appropriate weighting factor.

Operating Limits and Warnings

A value of D must always be entered (e.g., $D = 1$ in the case of the normal, or "special" von Bertalanffy Growth Formula). Also note that the value of t_o can be used only when the ages entered were absolute ages (see manual for more details).

FB 3: VON BERTALANFFY PLOT

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM			* FB 3 *
1.	DISPLAY OF MENU			MENU
1.1	LENGTH GROWTH			LENGTH GR.: A
1.2	WEIGHT GROWTH			WEIGHT GR.: B
1.3	{			MENU: C
1.4	{ SEE GENERAL			INIT.: c
1.5	{ INSTRUCTIONS			REV. DATA: D
1.6	{			REV. RES.: E
2.	INPUT OPTION			
2.1	COMPUTE GROWTH PARAMETERS USING LENGTH DATA		A	NO. OF ROWS ?
2.2	COMPUTE GROWTH PARAMETERS USING WEIGHT DATA		B	NO. OF ROWS ?
3.	ENTER NO. OF ROWS	k	R/S	WEIGHT. F ? YES: 1, NO: 0
4.	INDICATE WHETHER YOU WANT TO USE ("1") OR NOT USE ("0") A WEIGHTING FACTOR	1 OR 2	R/S	AGE INPUT IN: Y/M/D ? (1,2,3)
5.	INDICATE WHETHER YOUR AGE DATA ARE EXPRESSED IN YEARS (1), MONTHS (2) OR DAYS (3)	1,2, OR 3	R/S	SELECT: FIX S<00>: 1 ITER. S<00>: 2
6.	OPTION			
6.1	COMPUTE GROWTH PARAMETERS WITH A PRESELECTED VALUE OF ASYMPTOTIC SIZE (S = L OR W) TO DO SO ENTER AND ENTER PRESELECTED L OR W	1 L OR W	R/S R/S	ENTER: (S)<00> ENTER: D
6.2	COMPUTE GROWTH PARAMETERS WITH THE PROGRAM SELECTING THE BEST L /W VIA ITERATION ROUTINE. TO DO SO, ENTER	 2	 R/S	 ENTER: D
7.	ENTER D IN CASE YOU HAVE OPTED FOR WEIGHT GROWTH	D	R/S	ENTER: b*

FB 3: VON BERTALANFFY PLOT

USER INSTRUCTIONS (cont.)

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
8.	ENTER EXPONENT OF L/W REL. (b)	b	R/S	1. ROW:
9.	ENTER ROW 1,2 ... k:			(SIZE) ?
9.1	SIZE (S = LENGTH OR WEIGHT)	(S)	R/S	AGE ?
9.2	AGE T	t	R/S	WEIGHT. F ?
9.3	WEIGHTING FACTOR (IF OPTED FOR)	W.F.	R/S	2.,3 .. k: ROW
10.	AFTER LAST INPUT DATA CAN BE REVIEWED (SEE GENERAL INSTRUCTIONS)			REVIEW ? YES: 1, NO: 0
11.	COMPUTATION PROCEDURE (WITH DISPLAY OF STEP SIZES IF YOU HAVE OPTED FOR ITERATION ROUTINE)			PLEASE WAIT
12.	DISPLAY OF RESULTS:			
12.1	ASYMPTOTIC SIZE (L_{∞} , W_{∞})			(S) < ∞ >: (x)
12.2	K (ON ANNUAL BASIS)			K : (x)
12.3	r^{2t_0} (ON ANNUAL BASIS) ^{a)}			T<0> : (x)
12.4				R^2 : (x)
13.	OPTION:			
13.1	REVIEW RESULTS		E	(RESULTS)
13.2	CONTINUE WITH PROGRAM		R/S	OPTION:
14.	OPTION :			FIX (S) <00>?
	COMPUTE GROWTH PARAMETERS FOR DATA SET ENTERED USING PRESELECTED VALUE OF ASYMPTOTIC SIZE			YES: 1 NO: 0
14.1	TO DO SO, ENTER	1	R/S	(S) <00> ?
14.1.1	ENTER ASYMPTOTIC SIZE (FOR RESULTS, SEE 12.)	L_{∞} OR W_{∞}	R/S	PLEASE WAIT (RESULTS)
14.2	RETURN TO MENU	0	R/S	MENU:
15.	FOR A NEW SET OF DATA, INITIALIZE		f(c)	* FB 3 *

a) NOTE : WITH RELATIVE AGES, THIS OUTPUT IS NOT t_0 !

REGISTERS, STATUS, FLAGS

PROGR. NAME: FB 3 (von Bertalanffy Plot)

STATUS : REG. (PROGR.): 192
SIZE (MIN.) : (k*3)+19 SIZE (MAX.): 127

FLAGS : 0 - 10

ASSIGNMENTS:

A: GENERAL COMMANDS

B: SPECIAL COMMANDS

INITIALIZE : (f)c
REVIEW RESULTS : E
RECALL MENU : C
REVIEW DATA : D

LENGTH GROWTH : A
WEIGHT GROWTH : B

REGISTERS :

SUB-

PROGR.: A B

00 :	D	D
01 :	-	B*
02 :	L_2^{∞}	W_2^{∞}
03 :	r	r
04 :	K	K
05 :	t<o>	t<o>
06 :	b	b
07 :	[u]	[u]
08 :	[u]	[u]
09 :	[u]	[u]
10 :	[u]	[u]
11 :	[u]	[u]
12 :	[u]	[u]
13 :	[u]	[u]
14 :	[u]	[u]
15 :	[u]	[u]
16 :	[u]	[u]
17 :	[u]	[u]
18 :	[u]	[u]
19 :	W.F.(1)	W.F.(1)
20 :	t(1)	t(1)
21 :	$L_t(1)$	$W_t(1)$
	.	.
	.	.
	W.F.(k)	W.F.(k)
	t(k)	t(k)
	$L_t(k)$	$W_t(k)$

NOTE: "k" REPRESENTS NUMBER OF CASES (= NO. OF ROWS)

Program Listing

(FB 3)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01	LBL "FB 3"	57	1	113	"I<00>"	169	PSE	225	LBL 12
02	LBL C	58	ST+ 03	114	RTN	170	LBL 09	226	"I : "
03	SREG 10	59	"WEIGHT. F. ?"	115	LBL 01	171	LBL "V"	227	ARCL IND X
04	CLRG	60	XEQ 14	116	"1. ROW :"	172	"INPUT NO. ?"	228	AVIEW
05	SF 27	61	X*0?	117	AVIEW	173	PROMPT	229	PSE
06	FIX 0	62	SF 05	118	PSE	174	3	230	RTN
07	CF 21	63	"AGE INPUT IN:"	119	SF 06	175	*	231	LBL 06
08	BEEP	64	AVIEW	120	LBL 00	176	1	232	"MORE "
09	" * FB 3 *"	65	PSE	121	LBL "R"	177	-	233	LBL 07
10	AVIEW	66	"Y/M/D? <1,2,3,>"	122	XEQ 05	178	19	234	"-REVIEW?"
11	10	67	PROMPT	123	PROMPT	179	+	235	XEQ 14
12	LBL "M"	68	SF IND X	124	"AGE ?"	180	FIX 2	236	X*0?
13	CF IND X	69	"SELECT :"	125	PROMPT	181	XEQ "U"	237	GTO "V"
14	DSE X	70	AVIEW	126	FC? 05	182	XEQ 12	238	"L"
15	GTO "M"	71	PSE	127	GTO 01	183	1	239	FS? 10
16	CF 00	72	"FIX "	128	"WEIGHT. F. ?"	184	-	240	"W"
17	LBL C	73	XEQ 24	129	PROMPT	185	"AGE"	241	"I<MAX> = "
18	"MENU :"	74	"I : 1"	130	GTO 02	186	FIX 3	242	FIX 2
19	AVIEW	75	AVIEW	131	LBL 01	187	XEQ 12	243	RCL 02
20	PSE	76	PSE	132	1	188	1	244	1
21	"LENGTH GR.: A"	77	PSE	133	LBL 02	189	-	245	-
22	AVIEW	78	"ITER. "	134	ISG 03	190	FC? 05	246	STO 09
23	PSE	79	XEQ 24	135	GTO 01	191	GTO 01	247	RCL IND X
24	"WEIGHT GR.: B"	80	"I: 2"	136	SF 09	192	"W.F."	248	STO 17
25	AVIEW	81	PROMPT	137	GTO 02	193	FIX 2	249	ARCL X
26	PSE	82	2	138	LBL 01	194	XEQ 12	250	AVIEW
27	"MENU: C"	83	X=Y?	139	CLA	195	LBL 01	251	PSE
28	AVIEW	84	GTO 01	140	ARCL 03	196	PSE	252	XEQ 40
29	PSE	85	LBL 23	141	"I. ROW :"	197	PSE	253	X*0?
30	"INITIAL.: c"	86	SF 08	142	AVIEW	198	TONE 7	254	GTO 01
31	AVIEW	87	XEQ 03	143	LBL 02	199	XEQ 40	255	"NEW L<MAX> ?"
32	PSE	88	XEQ 24	144	XEQ 01	200	X*0?	256	PROMPT
33	"REV. DATA : D"	89	PROMPT	145	XEQ 01	201	GTO 06	257	STO 17
34	AVIEW	90	STO 16	146	XEQ 01	202	RDN	258	LBL 01
35	PSE	91	FS? 00	147	FC?C 09	203	2	259	"RESULTS ?"
36	"REV. RES.: E"	92	GTO e	148	GTO "R"	204	+	260	XEQ 14
37	AVIEW	93	LBL 01	149	CF 06	205	STO L	261	X*0?
38	RTN	94	XEQ 03	150	CLA	206	"CORR. INPUT :"	262	GTO e
39	LBL B	95	"FD"	151	GTO 07	207	AVIEW	263	GTO C
40	SF 10	96	PROMPT	152	LBL 01	208	PSE	264	LBL 40
41	LBL A	97	STO 00	153	STO IND 02	209	SF 06	265	"CORRECTION ?"
42	19	98	FC? 10	154	ISG 02	210	XEQ 05	266	LBL 14
43	ENTER↑	99	GTO 01	155	RDN	211	XEQ 01	267	AVIEW
44	ENTER↑	100	XEQ 03	156	RTN	212	"AGE ?"	268	TONE 7
45	"NO. OF ROWS ?"	101	"Ib*"	157	LBL 05	213	XEQ 01	269	PSE
46	PROMPT	102	PROMPT	158	LBL "U"	214	FC? 05	270	"YES: 1, NO: 0"
47	STO 03	103	STO 01	159	"LENGTH"	215	GTO 06	271	PROMPT
48	3	104	GTO 01	160	FS? 10	216	"WEIGHT. F. ?"	272	RTN
49	*	105	LBL 03	161	"WEIGHT"	217	XEQ 01	273	LBL e
50	+	106	"ENTER : "	162	FC? 06	218	GTO 06	274	CF 21
51	3	107	RTN	163	RTN	219	LBL 01	275	"PLEASE WAIT"
52	10↑X	108	LBL 24	164	"I ?"	220	PROMPT	276	AVIEW
53	ST/ 03	109	FS? 10	165	RTN	221	STO IND L	277	FIX 1
54	/	110	"FW"	166	LBL 0	222	1	278	RCL 17
55	+	111	FC? 10	167	" * REVIEW *"	223	ST- L	279	.99
56	STO 02	112	"FL"	168	AVIEW	224	RTN	280	/

Program Listing

(FB 3 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
281	STO 02	337	GTO "K"	393	ENTER↑	449	ST+ 13	505	SF 13
282	FC? 08	338	FS?C 07	394	RCL 02	450	ISG 09	506	"T(0)"
283	STO 16	339	GTO 01	395	+	451	GTO "W"	507	XEQ 11
284	STO 17	340	SF 07	396	GTO "L"	452	LBL 20	508	RCL 03
285	30	341	GTO "K"	397	LBL 30	453	RCL 14	509	"R+2"
286	STO 18	342	LBL 01	398	CLS	454	RCL 10	510	XEQ 11
287	RCL 09	343	2	399	INT	455	RCL 12	511	CF 13
288	XEQ 30	344	ST/ 18	400	3	456	*	512	ADV
289	FC? 08	345	RDN	401	101X	457	RCL 15	513	CF 21
290	GTO 22	346	GTO "K"	402	/	458	/	514	SF 00
291	XEQ 21	347	LBL 08	403	19	459	-	515	"CONT.: R/S"
292	GTO E	348	CLA	404	+	460	STO 08	516	PROMPT
293	LBL 22	349	ARCL X	405	STO 09	461	X+2	517	"OPTION :"
294	LBL "K"	350	"F % STEP"	406	LBL 17	462	RCL 13	518	AVIEW
295	XEQ 21	351	AVIEW	407	LBL "W"	463	RCL 12	519	PSE
296	RCL 18	352	RTN	408	RCL IND 09	464	X+2	520	"FIX "
297	ENTER↑	353	LBL 21	409	STO 08	465	RCL 15	521	XEQ 24
298	ABS	354	STO 03	410	ST+ 15	466	/	522	"F 2"
299	.1	355	RCL 08	411	ISG 09	467	-	523	XEQ 14
300	XYY?	356	RCL 06	412	RCL IND 09	468	/	524	X=0?
301	SF 09	357	/	413	STO 07	469	RCL 11	525	GTO C
302	RDN	358	STO 07	414	ENTER↑	470	RCL 10	526	1
303	XEQ 08	359	CHS	415	X+2	471	X+2	527	ST- 09
304	RDN	360	RCL 00	416	RCL Z	472	RCL 15	528	GTO 23
305	%	361	/	417	*	473	/	529	LBL 10
306	STO Z	362	STO 04	418	ST+ 11	474	-	530	ADV
307	+	363	RCL 12	419	RDN	475	STO 06	531	ADV
308	FS? 04	364	RCL 07	420	*	476	/	532	SF 12
309	XEQ 34	365	RCL 10	421	ST+ 10	477	RCL 03	533	"FB 3"
310	XEQ 13	366	*	422	ISG 09	478	X<>Y	534	ACA
311	XYY?	367	-	423	RCL IND 09	479	RTN	535	PRBUF
312	GTO 02	368	RCL 15	424	RCL 16	480	LBL E	536	"RESULTS"
313	FS?C 09	369	/	425	/	481	BEEP	537	ACA
314	GTO 01	370	RCL 07	426	RCL 00	482	CF 04	538	PRBUF
315	-2	371	CHS	427	FC? 10	483	SF 21	539	CF 12
316	ST/ 18	372	/	428	GTO 01	484	FC? 55	540	ADV
317	RDN	373	STO 05	429	RCL 01	485	GTO 01	541	RTN
318	FC?C 04	374	RCL 16	430	/	486	FC? 00	542	LBL 11
319	SF 04	375	STO 02	431	LBL 01	487	XEQ 10	543	"F "
320	GTO "K"	376	RTN	432	Y+X	488	LBL 01	544	FS? 55
321	LBL 01	377	LBL 13	433	CHS	489	FIX 2	545	GTO 15
322	RCL 02	378	STO 16	434	1	490	RCL 02	546	ARCL X
323	XEQ 13	379	RCL 09	435	+	491	CLA	547	AVIEW
324	GTO E	380	1	436	LN	492	XEQ 24	548	RTN
325	LBL 02	381	-	437	ENTER↑	493	XEQ 11	549	LBL 15
326	FC? 09	382	GTO 30	438	ENTER↑	494	FIX 3	550	ACA
327	GTO 02	383	LBL 34	439	RCL 08	495	XEQ 50	551	ACX
328	RCL 18	384	LBL "L"	440	*	496	RCL 04	552	PRBUF
329	SIGN	385	RCL 17	441	ST+ 12	497	X<>Y	553	RTN
330	.1	386	X<>Y	442	RCL 07	498	*	554	LBL 50
331	*	387	XYY?	443	*	499	"K"	555	1
332	STO 18	388	RTN	444	ST+ 14	500	XEQ 11	556	FS? 01
333	RDN	389	RCL Z	445	RDN	501	XEQ 50	557	RTN
334	GTO "K"	390	2	446	X+2	502	RCL 05	558	12
335	LBL 02	391	/	447	RCL 08	503	X<>Y	559	FS? 03
336	FC? 04	392	ENTER↑	448	*	504	/	560	365

EXAMPLE 3.3

(See also page 42 in manual)

Data from Appendix I,
Tab. 4.2

**FB 3
RESULTS**

L<00> : 101.31
K : 1.966
t<o> : -2.741-04
rt2 : 0.962

L<00> : 127.00
K : 1.111
t<o> : -0.092
rt2 : 0.953

L<00> : 120.00
K : 1.254
t<o> : -0.074
rt2 : 0.955

3.4: PROGRAM DESCRIPTION FB 4

Ford-Walford Plot (GM)

When size-at-age data at equal time interval (year, month) are available, 2 parameters of the VBGF can be estimated from

$$L_{t+1} = a + b L_t \quad \dots 1)$$

where $L_{\infty} = (a/(1 - b))^{1/D} \quad \dots 2)$

and $K = (-\ln b)/D \quad \dots 3)$

However, since both L_t and L_{t+1} are measured with the same error, a geometric mean, or type II regression is used. For this purpose, the parameters a and b of an arithmetic mean, or type I regression are first calculated, then used in conjunction with the absolute value of the correlation coefficient ($|r|$) estimated along with a and b to obtain the slope and intercept of the GM regression through the relationships

$$b' = b/|r| \quad \dots 4)$$

and $a' = \bar{Y} - (b' \bar{X}) \quad \dots 5)$

where $\bar{Y}$, $\bar{X}$ are the means of the L_{t+1} , L_t values and a' , b' are parameters of the GM or "functional" regression, respectively (Ricker, 1973, 1975).

Operating Limits and Warnings

Size-at-age data must be equidistant, and there must be at least 2 pairs (rows) of L_{t+1} , L_t values. When weight-at-age data are used, the exponent of the length/weight relationship (b) must be entered (e.g.. $b = 3$).

A value of D must be entered; when using the normal, or "special" VBGF, enter $D = 1$.

FB 4: FORD-WALFORD PLOT

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM			* FB 4 *
1.	DISPLAY OF MENU:			MENU
1.1	LENGTH GROWTH			LENGTH GR.: A
1.2	WEIGHT GROWTH			WEIGHT GR.: B
1.3	{			MENU : C
1.4	{ SEE GENERAL			INIT. : c
1.5	{ INSTRUCTIONS			REV. INPUT: D
1.6	{			REV. RES. : E
2.	INPUT OPTION:			
2.1	GROWTH PARAMETERS, USING LENGTH DATA		A	LENGTH
2.2	GROWTH PARAMETERS, USING WEIGHT DATA		B	WEIGHT
				:
				NO. OF ROWS ?
3.	ENTER NO. OF ROWS	k	R/S	AGE IN: Y/M/D: <1,2,3>
4.	INDICATE WHETHER THE TIME INTERVAL BETWEEN YOUR SIZE DATA IS IN YEARS (1), MONTHS (2), OR DAYS (3)	1,2,3	R/S	ENTER: D ?
5.	ENTER D IN CASE YOU HAVE OPTED FOR WEIGHT GROWTH	D	R/S	... b* ? :
6.	ENTER EXPONENT OF L/W REL. (b)	b	R/S	1. ROW: (Size) ?
7.	ENTER FOR ROW 1,2, ... k SIZE (S: LENGTH OR WEIGHT)	S	R/S	2., 3., ... k, ROW:
8.	BEFORE ENTERING SIZE DATA, PRECEDING INPUT CAN BE REVISED (SEE GENERAL INSTRUCTIONS)		D	LAST INPUT: PLEASE WAIT
9.	DISPLAY OF RESULTS:			(S)<00>: (x)
9.1	ASYMPTOTIC SIZE (S=L OR W)			K : (x)
9.2	K ₂ (ON ANNUAL BASIS)			R^2 : (x)
9.3	r ²			(RESULTS)
10.	TO REVIEW DATA, PRESS		E	
11.	FOR A NEW SET OF DATA, INITIALIZE		f c	* FB 4 *

REGISTERS, STATUS, FLAGS

PROGR. NAME: FB 4 (Ford-Walford Plot)

STATUS : REG. (PROGR.): 112
 : SIZE (MIN.) : 016 SIZE (MAX.): -

FLAGS : 1 - 3, 5 - 7, 9, 10

ASSIGNMENTS:

A: GENERAL COMMANDS

B: SPECIAL COMMANDS

INITIALIZE : (f)c
REVIEW RESULTS : E
RECALL MENU : C
REVIEW DATA : D

LENGTH GROWTH : A
WEIGHT GROWTH : B

REGISTERS :

SUB-

PROGR.: A B

00 :	[u]	[u]
01 :	D	D
02 :	$-_2$	b^*_2
03 :	r	r
04 :	a'	a'
05 :	b'	b'
06 :	K	K
07 :	L< ∞ >	W< ∞ >
08 :	[u]	[u]
09 :	[u]	[u]
10 :	[u]	[u]
11 :	[u]	[u]
12 :	[u]	[u]
13 :	[u]	[u]
14 :	[u]	[u]
15 :	[u]	[u]

Program Listing

(FB 4)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01	LBL "FB 4"	57	STO 00	113	"LAST INPUT :"	169	STO 05	225	GTO 01
02	LBL C	58	"AGE IN :"	114	AVIEW	170	X↑2	226	BEEP
03	CF 21	59	AVIEW	115	PSE	171	RCL 13	227	LBL E
04	BEEP	60	PSE	116	FIX 3	172	RCL 12	228	FS? 05
05	" * FB 4 * "	61	"Y/M/D? (1,2,3,)"	117	6	173	X↑2	229	SF 07
06	XEQ "Q"	62	PROMPT	118	"L"	174	RCL 15	230	FIX 2
07	SF 27	63	SF IND X	119	FS? 10	175	/	231	"L"
08	10	64	"ENTER :"	120	"W"	176	-	232	FS? 10
09	LBL "M"	65	AVIEW	121	XEQ "P"	177	/	233	"W"
10	CF IND X	66	PSE	122	"CORRECTION ?"	178	RCL 11	234	"H<00>"
11	DSE X	67	"D ?"	123	XEQ 14	179	RCL 10	235	7
12	GTO "M"	68	PROMPT	124	X=0?	180	X↑2	236	XEQ "P"
13	CF 00	69	STO 01	125	GTO 01	181	RCL 15	237	FIX 3
14	SREG 10	70	FC? 10	126	DSE 00	182	/	238	"K"
15	CLRG	71	GTO 01	127	LBL "Y"	183	-	239	6
16	LBL C	72	"b* ?"	128	XEQ 07	184	ST/ 05	240	XEQ "P"
17	"MENU :"	73	PROMPT	129	XEQ 10	185	/	241	"R↑2"
18	AVIEW	74	STO 02	130	STO 06	186	STO 03	242	3
19	PSE	75	LBL 01	131	ISG 00	187	SORT	243	XEQ "P"
20	PSE	76	SF 07	132	LBL 01	188	ST/ 05	244	FC? 07
21	"LENGTH GR.: A"	77	GTO "Y"	133	FC? 06	189	RCL 12	245	STOP
22	AVIEW	78	LBL "R"	134	XEQ 07	190	RCL 05	246	GTO 03
23	PSE	79	FC? 06	135	GTO "R"	191	RCL 10	247	LBL 01
24	PSE	80	XEQ 10	136	LBL 10	192	*	248	XEQ "S"
25	"WEIGHT GR.: B"	81	X<> 06	137	TONE 7	193	-	249	SF 21
26	AVIEW	82	RCL 01	138	"LENGTH"	194	RCL 15	250	ADV
27	PSE	83	FC? 10	139	FS? 10	195	/	251	FIX 2
28	PSE	84	GTO 01	140	"WEIGHT"	196	STO 04	252	"L"
29	"MENU : C"	85	RCL 02	141	"H ?"	197	RCL 05	253	FS? 10
30	AVIEW	86	/	142	PROMPT	198	LH	254	"W"
31	PSE	87	LBL 01	143	RTN	199	CHS	255	"H<00>"
32	"INIT.: c"	88	Y↑X	144	LBL 14	200	RCL 01	256	7
33	AVIEW	89	STO 09	145	AVIEW	201	/	257	XEQ "X"
34	PSE	90	FS? 06	146	TONE 7	202	STO 06	258	FIX 3
35	"REV. INPUT : D"	91	GTO 02	147	PSE	203	XEQ "W"	259	"K"
36	AVIEW	92	ISG 00	148	"YES: 1, NO: 0"	204	RCL 06	260	6
37	PSE	93	GTO 01	149	PROMPT	205	X<>Y	261	XEQ 01
38	"REV. RES.: E"	94	SF 09	150	RTN	206	*	262	SF 13
39	PROMPT	95	GTO 02	151	LBL 07	207	STO 06	263	"R↑2"
40	GTO C	96	LBL 01	152	FIX 0	208	RCL 04	264	3
41	LBL B	97	XEQ 07	153	CLA	209	1	265	XEQ 02
42	SF 10	98	LBL 02	154	ARCL 00	210	RCL 05	266	CF 13
43	"WEIGHT"	99	FS?C 07	155	"H. ROW :"	211	-	267	CF 21
44	XEQ "Q"	100	GTO 01	156	AVIEW	212	/	268	GTO 03
45	GTO 01	101	RCL 09	157	PSE	213	RCL 01	269	LBL 01
46	LBL A	102	RCL 08	158	RTN	214	1/X	270	"H "
47	"LENGTH"	103	Σ+	159	LBL 04	215	FC? 10	271	LBL 02
48	XEQ "Q"	104	LBL 01	160	"PLEASE WAIT"	216	GTO 01	272	"H "
49	LBL 01	105	RCL 09	161	AVIEW	217	RCL 02	273	GTO "X"
50	"NO. OF ROWS ?"	106	STO 08	162	RCL 14	218	*	274	LBL 03
51	PROMPT	107	FS? 06	163	RCL 10	219	LBL 01	275	SF 05
52	3	108	GTO 04	164	RCL 12	220	Y↑X	276	STOP
53	10↑X	109	FC? 09	165	*	221	STO 07	277	GTO E
54	/	110	GTO "R"	166	RCL 15	222	CF 05	278	LBL "W"
55	1	111	SF 06	167	/	223	CF 07	279	1
56	+	112	LBL D	168	-	224	FS? 55	280	FS? 01

Program Listing

(FB 4 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
281	RTN								
282	12								
283	FS? 03								
284	365								
285	12								
286	X\Y								
287	RTN								
288	LBL "P"								
289	"P : "								
290	ARCL IND X								
291	AVIEW								
292	PSE								
293	PSE								
294	RTN								
295	LBL "X"								
296	"X : "								
297	ACA								
298	RCL IND X								
299	ACX								
300	PRBUF								
301	RTN								
302	LBL "Q"								
303	AVIEW								
304	PSE								
305	FC? 55								
306	RTN								
307	SF 21								
308	ADV								
309	ADV								
310	SF 12								
311	GTO 01								
312	LBL "S"								
313	"RESULTS : "								
314	BEEP								
315	AVIEW								
316	FC? 55								
317	RTN								
318	SF 21								
319	ADV								
320	LBL 01								
321	ACA								
322	PRBUF								
323	CF 12								
324	CF 21								
325	.END.								

EXAMPLE 3.4

(See also page 44 in manual)

Data from Appendix I,
Tab. 4.4

* FB 4 *

LENGTH

RESULTS :

L <00> : 186.60

K : 0.150

r12 : 0.996

* FB 4 *

LENGTH

RESULTS :

L <00> : 153.93

K : 0.583

r12 : 0.998

3.5: PROGRAM DESCRIPTION FB 5

Gulland and Holt Plot

Gulland and Holt (1969) demonstrated that estimates of K and L_{∞} can be obtained by means of the relationship

$$\frac{\Delta L}{\Delta t} = a + b \frac{L_1 + L_2}{2} \quad \dots 1)$$

where L_1 and L_2 are the lengths of fishes at time t_1 and t_2 , respectively and $\Delta L/\Delta t$ stands for $(L_2 - L_1)/(t_2 - t_1)$. When the periods $\Delta t (= t_2 - t_1)$ is short relative to the total life span of the fish, the equation yields an estimation of K through

$$K \approx -b \quad \dots 2)$$

while L_{∞} is estimated through

$$L_{\infty} \approx a/-b \quad \dots 3)$$

These equations can be easily expanded to cases pertaining to growth in weight by using values of $W^{1/3}$ instead of the length values, and to the generalized VBGF by replacing the length values by L^D values.

A set value for the asymptotic size ($L_{(\infty)}$) may be used in which case a "forced" Gulland and Holt Plot results, i.e.,:

$$K \approx L_{(\infty)} \frac{Y}{-X} \quad \dots 4)$$

where Y is the mean of the $\Delta L/\Delta t$ values and X the mean of the $(L_1 + L_2)/2$ values, and which can be easily expanded to weight growth and to the generalized VBGF.

Operating Limits and Warnings

1) A value of D must be entered, i.e., $D = 1$, in the case of the special VBGF and $D < 1$ in the case of the generalized VBGF.

2) The original paper by Gulland and Holt (1959) should be consulted for a method (and table) to estimate the error involved in using the approximations in equations (2) and (3).

FB 5: GULLAND AND HOLT PLOT

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM			* FB 5 *
1.	DISPLAY OF MENU			MENU:
1.1	LENGTH GROWTH			LENGTH GR.: A
1.2	WEIGHT GROWTH			WEIGHT GR.: B
1.3	{			MENU : C
1.4	{ SEE GENERAL			INIT. : c
1.5	{ INSTRUCTIONS			REV. INPUT: D
1.6	{			REV. RES. : E
2.	INPUT OPTION			
2.1	GROWTH PARAMETERS, USING LENGTH DATA		A	LENGTH
2.2	GROWTH PARAMETERS, USING WEIGHT DATA		B	WEIGHT
3.	INDICATE WHETHER YOU WANT TO USE ("1") OR NOT USE ("0") A SET VALUE OF ASYMPTOTIC SIZE (S = L OR W)			FIX(S) <00> ? YES: 1, NO:0
3.1	USED:	1	R/S	ENTER: (S) <00> ?
3.1.1	ENTER ASYMPTOTIC SIZE	L ∞ OR W ∞	R/S	:
3.2	NOT USED:	0 ∞	R/S	PLOT OUTPUT ? YES: 1, NO: 0
4.	INDICATE WHETHER YOU WANT ("1") OR DO NOT WANT ("0") THE DATA PAIRS DISPLAYED IN ORDER TO DRAW A SCATTERGRAM	1 OR 0	R/S	NO. OF ROWS ?
5.	ENTER NO. OF ROWS	k	R/S	TIME INP. IN: Y/M/D ? <1,2,3>
6.	INDICATE WHETHER TIME INPUT IS IN YEARS ("1"), MONTHS ("2"), OR DAYS ("3")	1,2 OR 3	R/S	ENTER : D ?
7.	ENTER D IN CASE YOU HAVE OPTED FOR WEIGHT GROWTH	D	R/S	: b* ?:
8.	ENTER EXPONENT OF L/W REL. (b)	b	R/S	1. ROW: (S) <1> ?

FB 5: GULLAND AND HOLT PLOT

USER INSTRUCTIONS (cont.)

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
9.	ENTER FOR ROW 1, 2, ... k			
9.1	SIZE AT t_1 (S = L OR W)	S_1	R/S	(S) <2> ?
9.2	SIZE AT t_2 (S = L OR W)	S_2	R/S	T<2>-T<1> ?
9.3	TIME AT LARGE	Δt	R/S	2., 3., ... k ROW:
10.	BEFORE ENTERING SIZE DATA, PRECEDING INPUT CAN BE REVIEWED (SEE GENERAL INSTRUCTIONS)		D	LAST INPUT:
11.	IF OPTION "PLOT OUTPUT" WAS SELECTED:			FOR PLOT:
11.1	X-VARIABLE: MEAN SIZE (S=L OR W)			<S>: (x)
11.2	Y-VARIABLE: $\Delta S/\Delta t$ (S = L OR W)		R/S	dS/dT: (x)
			R/S	(n.) ROW:
12.	DISPLAY OF RESULTS			
12.1	OPTION: SET VALUE OF ASYMPT. SIZE:			
12.1.1	ASYMPTOTIC SIZE (SET)			S <00>: (x)
12.1.2	K (ON ANNUAL BASIS)			K : (x)
12.2	OPTION: NO SET VALUE OF ASYMPT. SIZE:			
12.2.1	ASYMPTOTIC SIZE (COMPUTED)			S <00>: (x)
12.2.2	K_2 (ON ANNUAL BASIS)			K : (x)
12.2.3	r^2			R^2 : (x)
13.	TO REVIEW DATA, PRESS		E	(RESULTS)
14.	FOR A NEW SET OF DATA, INITIALIZE		f c	* FB 5 *

REGISTERS, STATUS, FLAGS

PROGR. NAME: FB 5 (Gulland and Holt Plot)

STATUS : REG. (PROGR.): 175
SIZE (MIN.) : 017 SIZE (MAX.): -

FLAGS : 0 - 10

ASSIGNMENTS:

A: GENERAL COMMANDS

B: SPECIAL COMMANDS

INITIALIZE : (f)c
REVIEW RESULTS : E
RECALL MENU : C
REVIEW DATA : D

LENGTH GROWTH : A
WEIGHT GROWTH : B

REGISTERS :

SUB-

PROGR.: A B

00 :	[u]	[u]
01 :	D	D
02 :	r^2	b^*
03 :	r^2	r^2
04 :	a	a
05 :	b	b
06 :	$L<\infty>$	$W<\infty>$
07 :	K	K
08 :	MEAN $\Delta L/\Delta t$	MEAN $\Delta W/\Delta t$
09 :	[u]	[u]
10 :	[u]	[u]
11 :	[u]	[u]
12 :	[u]	[u]
13 :	[u]	[u]
14 :	[u]	[u]
15 :	[u]	[u]
16 :	[u]	[u]

Program Listing

(FB 5)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01	LBL "FB 5"	57	ASTO X	113	GTO "Y"	169	LBL D	225	FS? 10
02	LBL C	58	"FIX "	114	LBL "P"	170	"LAST INPUT "	226	"W"
03	CF 21	59	ARCL X	115	FC? 06	171	AVIEW	227	"F<"
04	BEEP	60	"H<00> ?"	116	XEQ 10	172	PSE	228	ARCL X
05	" * FB 5 * "	61	XEQ 14	117	X<> 05	173	3	229	"F> ?"
06	XEQ "G"	62	X=0?	118	STO 06	174	1	230	X<>Y
07	SF 27	63	GTO 01	119	RDW	175	XEQ 01	231	PROMPT
08	10	64	SF 04	120	X<> 04	176	4	232	RTN
09	LBL "M"	65	"ENTER :"	121	STO 07	177	2	233	LBL 14
10	CF IND X	66	AVIEW	122	X<>Y	178	XEQ 01	234	AVIEW
11	DSE X	67	PSE	123	X<> 03	179	5	235	TONE 7
12	GTO "M"	68	"L"	124	XEQ 01	180	"dT"	236	PSE
13	CF 00	69	FS? 10	125	X<> 07	181	XEQ "P"	237	"YES: 1, NO: 0"
14	CREG 10	70	"W"	126	XEQ 01	182	GTO 02	238	PROMPT
15	CLRG	71	"H<00> ?"	127	ENTER	183	LBL 01	239	RTN
16	LBL C	72	PROMPT	128	ENTER	184	FIX 0	240	LBL 07
17	"MENU :"	73	STO 16	129	RCL 07	185	"L"	241	FIX 0
18	AVIEW	74	FC? 55	130	ST- Z	186	FS? 10	242	CLA
19	PSE	75	GTO 01	131	+	187	"W"	243	ARCL 00
20	PSE	76	SF 21	132	2	188	"F<"	244	"F. ROW "
21	"LENGTH GR.: A"	77	ADV	133	/	189	ARCL X	245	AVIEW
22	AVIEW	78	"G. + H.-PLOT :"	134	STO 09	190	"F>"	246	PSE
23	PSE	79	ACB	135	X<>Y	191	X<>Y	247	RTN
24	PSE	80	PRBUF	136	RCL 06	192	FIX 2	248	LBL 04
25	"WEIGHT GR.: B"	81	CF 21	137	/	193	GTO "P"	249	"PLEASE WAIT"
26	AVIEW	82	LBL 01	138	STO 08	194	LBL 02	250	AVIEW
27	PSE	83	"PLOT OUTPUT?"	139	FC? 00	195	"CORRECTION ?"	251	RCL 14
28	PSE	84	XEQ 14	140	XEQ "D"	196	XEQ 14	252	RCL 10
29	"MENU : C"	85	X=0?	141	GTO 02	197	X=0?	253	RCL 12
30	AVIEW	86	SF 00	142	LBL 01	198	GTO 01	254	*
31	PSE	87	"NO. OF ROWS ?"	143	RCL 01	199	DSE 00	255	RCL 15
32	"INIT.: C"	88	PROMPT	144	FC? 10	200	LBL "Y"	256	/
33	AVIEW	89	3	145	GTO 01	201	XEQ 07	257	-
34	PSE	90	101X	146	RCL 02	202	XEQ 10	258	STO 05
35	"REV. INPUT : D"	91	/	147	/	203	STO 05	259	X+2
36	AVIEW	92	1	148	LBL 01	204	RDW	260	RCL 13
37	PSE	93	+	149	Y+X	205	STO 04	261	RCL 12
38	"REV. RES.: E"	94	STO 00	150	RTN	206	X<>Y	262	X+2
39	PROMPT	95	"TIME INP. IN :"	151	LBL 02	207	STO 03	263	RCL 15
40	GTO C	96	AVIEW	152	FS? 06	208	ISG 00	264	/
41	LBL E	97	PSE	153	GTO 02	209	LBL 01	265	-
42	FC? 00	98	"Y/M/D? <1,2,3>"	154	ISG 00	210	FC? 06	266	/
43	GTO "M"	99	PROMPT	155	GTO 01	211	XEQ 07	267	RCL 11
44	GTO "Z"	100	SF IND X	156	SF 09	212	GTO "R"	268	RCL 10
45	LBL B	101	"ENTER :"	157	GTO 02	213	LBL 10	269	X+2
46	SF 10	102	AVIEW	158	LBL 01	214	TONE 7	270	RCL 15
47	"WEIGHT"	103	PSE	159	XEQ 07	215	FIX 0	271	/
48	XEQ "0"	104	"D ?"	160	LBL 02	216	1	272	-
49	GTO 01	105	PROMPT	161	RCL 08	217	XEQ 01	273	ST/ 05
50	LBL A	106	STO 01	162	RCL 09	218	2	274	/
51	"LENGTH"	107	FC? 10	163	Z+	219	XEQ 01	275	STO 03
52	XEQ "0"	108	GTO 01	164	FS? 06	220	"T<2>-T<1> ?"	276	RCL 12
53	LBL 01	109	"b* ?"	165	GTO 04	221	PROMPT	277	RCL 05
54	"L"	110	PROMPT	166	FC? 09	222	RTN	278	RCL 10
55	FS? 10	111	STO 02	167	GTO "R"	223	LBL 01	279	*
56	"W"	112	LBL 01	168	SF 06	224	"L"	280	-

Program Listing

(FB 5 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
281	RCL 15	337	FS? 05	393	PRBUF	449	PRBUF	505	"H (MEAN)"
282	.	338	SF 07	394	RTN	450	RTN	506	9
283	STO 04	339	FIX 2	395	LBL 01	451	LBL "0"	507	FIX 2
284	RCL 12	340	"L"	396	XEQ "S"	452	AVIEW	508	XEQ "X"
285	RCL 15	341	FS? 10	397	SF 21	453	PSE	509	"dL"
286	/	342	"W"	398	FIX 2	454	FC? 55	510	FS? 10
287	STO 09	343	"H<00>"	399	"L"	455	RTN	511	"dW"
288	RCL 10	344	6	400	FS? 10	456	SF 21	512	"H/dT"
289	RCL 15	345	XEQ "P"	401	"W"	457	ADV	513	6
290	/	346	FIX 3	402	"H <00>"	458	ADV	514	FIX 4
291	STO 08	347	"K"	403	6	459	SF 12	515	XEQ "X"
292	FS? 04	348	7	404	XEQ "X"	460	GTO 01	516	CF 21
293	GTO 01	349	XEQ "P"	405	FIX 3	461	LBL "S"		
294	RCL 04	350	FS? 04	406	"K"	462	"RESULTS :"		
295	RCL 05	351	GTO 02	407	7	463	BEEP		
296	/	352	"R+2"	408	XEQ 01	464	AVIEW		
297	CHS	353	3	409	FS? 04	465	FC? 55		
298	RCL 01	354	XEQ "P"	410	GTO 03	466	RTN		
299	1/Y	355	LBL 02	411	SF 13	467	SF 21		
300	FC? 10	356	FC? 07	412	"R+2"	468	ADV		
301	GTO 02	357	STOP	413	3	469	LBL 01		
302	RCL 02	358	GTO 03	414	XEQ 02	470	ACA		
303	*	359	LBL 01	415	CF 13	471	PRBUF		
304	LBL 02	360	FIX 2	416	LBL 03	472	CF 12		
305	Y+Y	361	FS? 00	417	CF 21	473	CF 21		
306	STO 06	362	GTO 01	418	GTO 03	474	RTN		
307	RCL 05	363	SF 21	419	LBL 01	475	LBL "0"		
308	RCL 01	364	ADV	420	"H "	476	FS? 55		
309	/	365	"L"	421	LBL 02	477	GTO 01		
310	CHS	366	FS? 10	422	"H "	478	LBL "N"		
311	GTO 02	367	"W"	423	GTO "X"	479	"FOR PLOT :"		
312	LBL 01	368	ASTO X	424	LBL 03	480	AVIEW		
313	RCL 09	369	"MEAN "	425	SF 05	481	PSE		
314	RCL 16	370	ARCL X	426	GTO C	482	PSE		
315	STO 06	371	8	427	LBL "W"	483	">L<"		
316	RCL 01	372	XEQ 02	428	1	484	FS? 10		
317	FC? 10	373	"dL"	429	FS? 01	485	">W<"		
318	GTO 01	374	FS? 10	430	RTN	486	9		
319	RCL 02	375	"dW"	431	12	487	FIX 2		
320	/	376	"H/dT "	432	FS? 03	488	XEQ "P"		
321	LBL 01	377	9	433	365	489	STOP		
322	Y+X	378	FIX 4	434	12	490	"dL"		
323	RCL 08	379	XEQ 02	435	X<Y	491	FS? 10		
324	-	380	ADV	436	RTN	492	"dW"		
325	/	381	CF 21	437	LBL "P"	493	"H/dT"		
326	LBL 02	382	GTO 01	438	"H : "	494	8		
327	STO 07	383	LBL 02	439	ARCL IND X	495	FIX 4		
328	XEQ "W"	384	"H <"	440	AVIEW	496	XEQ "P"		
329	ST* 07	385	ACA	441	PSE	497	STOP		
330	CF 05	386	2	442	PSE	498	RTN		
331	CF 07	387	ACCHR	443	RTN	499	LBL 01		
332	SF 08	388	X<Y	444	LBL "X"	500	SF 21		
333	FS? 55	389	"> : "	445	"H "	501	ADV		
334	GTO 01	390	ACA	446	ACA	502	"L"		
335	BEEP	391	RCL IND X	447	RCL IND X	503	FS? 10		
336	LBL "2"	392	ACX	448	ACX	504	"W"		

EXAMPLE 3.5

(See also page 45 and 46 in manual)

Data from Appendix I,
Tab. 4.5

Data from Appendix I,
Tab. 4.6

* FB 5 *

LENGTH

L <MEAN> : 9.95
dL/dT : 0.0094

L <MEAN> : 10.70
dL/dT : 0.0121

L <MEAN> : 11.35
dL/dT : 0.0083

L <MEAN> : 11.55
dL/dT : 0.0088

L <MEAN> : 13.95
dL/dT : 0.0114

L <MEAN> : 13.20
dL/dT : 0.0167

L <MEAN> : 14.15
dL/dT : 0.0057

L <MEAN> : 16.25
dL/dT : 0.0041

L <MEAN> : 16.40
dL/dT : 0.0032

L <MEAN> : 17.10
dL/dT : 0.0019

L <MEAN> : 17.85
dL/dT : 0.0027

MEAN L <x> : 13.86
dL/dT <x> : 0.0077

RESULTS :

L <00> : 20.34

K : 0.432

r² : 0.496

* FB 5 *

LENGTH

G.+ H.-PLOT :

L <MEAN> : 15.45
dL/dT : 0.0604

L <MEAN> : 24.20
dL/dT : 0.0360

L <MEAN> : 25.65
dL/dT : 0.0354

MEAN L <x> : 21.77
dL/dT <x> : 0.0439

RESULTS :

L <00> : 53.50

K : 0.505

Note that "L<MEAN>" stands for $(L_1 + L_2)/2$ values, "MEAN L <x>" for the mean of the "L<MEAN>" values, "dL/dT" stands for $\Delta L/\Delta t$, and "dL/dt <x>" stands for the mean of the growth rates, i.e., of the Y-values.

3.6: PROGRAM DESCRIPTION FB 6

Munro Plot

Munro (1982) suggested that

$$\log_e (L_{\infty} - L_a) - \log_e (L_{\infty} - L_b) = K(b-a) \quad \dots 1)$$

which becomes, in terms of the generalized VBGF and using a different notation

$$\ln (L_{(\infty)}^D - L_1^D) - \ln (L_{(\infty)}^D - L_2^D) = KD (t_2 - t_1) \quad \dots 2)$$

Given a value of D and a first value of $L_{(\infty)}$, equation (2) can be used to obtain single values of K (one for each triplet of L_1 , L_2 and $\Delta t (= t_2 - t_1)$ values). The calculated values of K have the property of being close to each other when an optimal value of $L_{(\infty)}$ has been selected, and to differ widely from each other when the selected value of $L_{(\infty)}$ is too high or too low. Thus, by calculating, for a given value of $L_{(\infty)}$ the coefficient of variation (C.V.) of the K-values (C.V. of K = s.d. of K-values/K), one can identify by iteration the value of $L_{(\infty)}$ which produces the lowest C.V. of the K-values and which thus corresponds to L_{∞} (= best $L_{(\infty)}$).

The method resembles the "forced" Gulland and Holt Plot in that data at unequal time interval can be used. It has, however, the advantage of providing exact solutions (= K-values) irrespective of the value of Δt . The iteration routine in this program starts (automatically) with a "seed" value of $L_{(\infty)} = L_{\max}/0.99$.

Operating Limits and Warnings

- 1) Input L_{∞} values must be higher than any L_2 value.
- 2) Δt values must be expressed in years, months or days.
- 3) The K-values are put on an annual basis automatically.
- 4) A value of D must be entered; set D = 1 when using the normal or "special" VBGF.

FB 6: MUNRO PLOT

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM			* FB 6 *
1.	DISPLAY OF MENU			MENU
1.1	LENGTH GROWTH			LENGTH GR.: A
1.2	WEIGHT GROWTH			WEIGHT GR.: B
1.3	{			MENU : C
1.4	{ SEE GENERAL			INIT. : c
1.5	{ INSTRUCTIONS			REV. DATA : D
1.6	{			REV. RES. : E
2.	INPUT OPTION:			
2.1	MEAN K AND C.V., USING LENGTH DATA		A	NO. OF ROWS ?
2.2	MEAN K AND C.V. USING WEIGHT DATA		B	NO. OF ROWS ?
3.	ENTER NO. OF ROWS	k	R/S	TIME INP. IN: Y/M/D ? (1,2,3):
4.	INDICATE WHETHER YOUR TIME DATA ARE EXPRESSED IN YEARS ("1"), MONTHS ("2") OR DAYS ("3")	1,2 OR 3	R/S	SELECT: FIX S<00>: 1 ITER. S<00>: 2
5.	OPTION:			
5.1	COMPUTE MEAN K AND C.V. WITH A PRESELECTED VALUE OF ASYMPTOTIC SIZE (S=L OR W):			
5.1.1	TO DO SO, ENTER	1	R/S	ENTER: S<00>
5.1.2	ENTER PRESELECTED ASYMPTOTIC SIZE	L_{∞}, W_{∞}	R/S	DISPL. K<N> ? YES: 1, NO: 0
5.1.3	INDICATE WHETHER YOU WANT TO ("1") OR DO NOT WANT TO ("0") HAVE THE SINGLE VALUES OF K DISPLAYED	1 OR 0	R/S	ENTER D
5.2	COMPUTE MEAN K AND C.V. WITH THE PROGRAM ESTIMATING L_{∞} OR W_{∞} BY ITERATION			
5.2.1	TO DO SO, ENTER	0	R/S	ENTER D
6.	ENTER D IN CASE YOU HAVE OPTED FOR WEIGHT GROWTH	D	R/S	ENTER b*:

FB 6: MUNRO PLOT

USER INSTRUCTIONS (cont.)

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
7.	ENTER EXPONENT OF L/W REL.	b	R/S	1. ROW: S<1> ?
8.	ENTER FOR ROW 1, 2, ... k:			
8.1	SIZE AT t_1 (S = L OR W)	S_1	R/S	S<2> ?
8.2	SIZE AT t_2 (S = L OR W)	S_2	R/S	T<2>-T<1> ?
8.3	TIME AT LARGE	Δt	R/S	2., 3., ... k. ROW:
9.	AFTER LAST INPUT, DATA CAN BE REVIEWED (SEE GENERAL INSTRUCTIONS)		D	REVIEW ? YES: 1, NO: 0
10.	COMPUTATION PROCEDURE WITH DISPLAY OF:			PLEASE WAIT
10.1	SINGLE K-VALUES FOR ROW 1,2,...k (IF "FIX S<00>" WAS OPTED FOR)			K<N> : (x)
10.2	STEP SIZE OF SEARCH ROUTINE (IF "ITER. S<00>" WAS OPTED FOR)			(x)% - STEP
11.	DISPLAY OF RESULTS			
11.1	ASYMPTOTIC SIZE (L_∞ , W_∞)			S<00>: (x)
11.2	MEAN K		R/S	K (MEAN): (x)
11.3	COEFFICIENT OF VARIATION		R/S	C.V.: (x)
12.	OPTION:			
12.1	REVIEW RESULTS		E	RESULTS
12.2	CONTINUE WITH NEXT PART OF PROGRAM		R/S	OPTION:
13.	COMPUTE SINGLE K-VALUES, MEAN K AND C.V. FOR GIVEN DATA SET USING PRESELECTED VALUES OF ASYMPTOTIC SIZE (S = L OR W)			FIX S <00> YES: 1, NO: 0
13.1	TO DO SO, ENTER	1	R/S	S <00> ?
13.2	AND ENTER ASYMPTOTIC SIZE	L_∞ OR W_∞	R/S	PLEASE WAIT (RESULTS)
14.	FOR A NEW SET OF DATA, INITIALIZE		f c	* FB 6 *

REGISTERS, STATUS, FLAGS

 PROGR. NAME: FB 6 (Munro Plot)

STATUS : REG. (PROGR.): 194
 SIZE (MIN.) : (k*3)+16 SIZE (MAX.): 125

FLAGS : 0 - 3, 5 - 10

ASSIGNMENTS:

A: GENERAL COMMANDS

B: SPECIAL COMMANDS

INITIALIZE : (f)c
 REVIEW RESULTS : E
 RECALL MENU : C
 REVIEW DATA : D

LENGTH GROWTH : A
 WEIGHT GROWTH : B

REGISTERS :

SUB-

PROGR.:	A	B
00 :	D	D
01 :	-	1/b*
02 :	[u]	[u]
03 :	L<∞>	W<∞>
04 :	MEAN K	MEAN K
05 :	C.V.	C.V.
06 :	[u]	[u]
07 :	[u]	[u]
08 :	[u]	[u]
09 :	[u]	[u]
10 :	[u]	[u]
11 :	[u]	[u]
12 :	[u]	[u]
13 :	[u]	[u]
14 :	[u]	[u]
15 :	[u]	[u]
16 :	t(1)	t(1)
17 :	L ₂ (1)	W ₂ (1)
18 :	L ₁ (1)	W ₁ (1)
	.	.
	.	.
	△t(k)	△t(k)
	L ₂ (k)	W ₂ (k)
	L ₁ (k)	W ₁ (k)

NOTE: "k" REPRESENTS NUMBER OF CASES (= NO. OF ROWS)

Program Listing

(FB 6)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01	LBL "FB 6"	57	1	113	PROMPT	169	LBL D	225	"I?"
02	LBL C	58	ST+ 09	114	XEQ 06	170	" * REVIEW *"	226	PROMPT
03	ΣREG 10	59	"TIME INP. IN :"	115	PROMPT	171	AVIEW	227	STO IND T
04	CLRG	60	AVIEW	116	XEQ 04	172	PSE	228	CF 06
05	SF 27	61	PSE	117	"I ?"	173	LBL 19	229	GTO 14
06	FIX 0	62	"Y/M/D? <1,2,3>"	118	PROMPT	174	"INPUT NO. ?"	230	LBL 12
07	CF 21	63	PROMPT	119	ISG 09	175	PROMPT	231	"I: "
08	BEEP	64	SF IND X	120	GTO 01	176	3	232	ARCL IND X
09	" * FB 6 * "	65	"SELECT :"	121	SF 09	177	*	233	AVIEW
10	AVIEW	66	AVIEW	122	GTO 02	178	1	234	PSE
11	10	67	PSE	123	LBL 01	179	-	235	RTN
12	LBL "M"	68	"FIX "	124	CLA	180	16	236	LBL 14
13	CF IND X	69	XEQ 44	125	ARCL 09	181	+	237	"MORE "
14	DSE X	70	"I: 1"	126	"I. ROW :"	182	XEQ 05	238	LBL 07
15	GTO "M"	71	AVIEW	127	AVIEW	183	FIX 2	239	"REVIEW?"
16	CF 00	72	PSE	128	LBL 02	184	XEQ 12	240	XEQ 41
17	LBL C	73	PSE	129	STO IND 03	185	1	241	X=0?
18	"MENU :"	74	"ITER. "	130	ISG 03	186	-	242	GTO 01
19	AVIEW	75	XEQ 44	131	RDN	187	XEQ 06	243	GTO 19
20	PSE	76	"I: 2"	132	RCL 02	188	FIX 2	244	LBL 01
21	"LENGTH GR.: A"	77	PROMPT	133	X<Y	189	XEQ 12	245	CLA
22	AVIEW	78	2	134	X<Y?	190	1	246	XEQ 02
23	PSE	79	X=Y?	135	STO 02	191	-	247	"I: "
24	"WEIGHT GR.: B"	80	GTO 01	136	STO IND 03	192	FIX 0	248	FIX 2
25	AVIEW	81	SF 08	137	ISG 03	193	XEQ 04	249	ARCL 02
26	PSE	82	XEQ 39	138	RCL 2	194	XEQ 12	250	AVIEW
27	"MENU: C"	83	XEQ 02	139	STO IND 03	195	PSE	251	PSE
28	AVIEW	84	XEQ 44	140	FS?C 09	196	XEQ 40	252	XEQ 40
29	PSE	85	PROMPT	141	GTO 01	197	X=0?	253	X=0?
30	"INITIAL.: C"	86	STO 08	142	ISG 03	198	GTO 14	254	GTO 01
31	AVIEW	87	1	143	GTO "R"	199	RDN	255	"CORR. "
32	PSE	88	STO 06	144	LBL 01	200	2	256	XEQ 02
33	"REV. DATA : D"	89	LBL 01	145	CF 06	201	+	257	"I?"
34	AVIEW	90	XEQ 02	146	CLA	202	"CORR. INPUT :"	258	PROMPT
35	PSE	91	"I-D"	147	GTO 07	203	AVIEW	259	STO 02
36	"REV. RES.: E"	92	PROMPT	148	LBL 04	204	PSE	260	GTO 01
37	AVIEW	93	STO 00	149	"T<2>-<1>"	205	SF 06	261	LBL 02
38	RTN	94	FC? 10	150	RTN	206	XEQ 05	262	"H"
39	LBL B	95	GTO 01	151	LBL 05	207	PROMPT	263	FS? 10
40	SF 10	96	XEQ 02	152	1	208	STO IND Y	264	"H"
41	LBL A	97	"I-b"	153	GTO 01	209	1	265	"I<MAX>"
42	16	98	PROMPT	154	LBL 06	210	ST- 2	266	RTN
43	ENTER↑	99	1/X	155	2	211	RDN	267	PROMPT
44	ENTER↑	100	STO 01	156	LBL 01	212	XEQ 06	268	STO 02
45	"NO. OF ROWS ?"	101	GTO 01	157	"W"	213	PROMPT	269	LBL 01
46	PROMPT	102	LBL 02	158	FC? 10	214	STO IND Z	270	"RESULTS ?"
47	STO 09	103	"ENTER : "	159	"L"	215	X<Y	271	XEQ 41
48	3	104	RTN	160	"I <"	216	RDN	272	X=0?
49	*	105	LBL 01	161	FIX 0	217	RCL 02	273	GTO e
50	+	106	"1. ROW :"	162	ARCL X	218	X<Y	274	GTO C
51	3	107	AVIEW	163	"I> "	219	X>Y?	275	LBL 40
52	10↑X	108	PSE	164	RDN	220	STO 02	276	"CORRECTION ?"
53	ST/ 09	109	SF 06	165	FC? 06	221	1	277	LBL 41
54	/	110	LBL 00	166	RTN	222	ST- T	278	TONE 7
55	+	111	LBL "R"	167	"I?"	223	RDN	279	AVIEW
56	STO 03	112	XEQ 05	168	RTN	224	XEQ 04	280	PSE

Program Listing

(FB 6 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
281	"YES: 1, NO: 0"	337	LBL 01	393	RCL 03	449	RTN	505	"C.V."
282	PROMPT	338	RCL 03	394	+	450	LBL 20	506	XEQ 38
283	RTN	339	XEQ 33	395	GTO "L"	451	MEAN	507	ADV
284	LBL e	340	GTO E	396	LBL 30	452	RCL 11	508	CF 21
285	CF 21	341	LBL 02	397	CLS	453	RCL 10	509	FC? 55
286	"PLEASE WAIT"	342	FC? 09	398	INT	454	X↑2	510	GTO 01
287	AVIEW	343	GTO 02	399	3	455	RCL 15	511	"CONT. R/S"
288	CF 05	344	RCL 06	400	10↑X	456	/	512	PROMPT
289	CF 07	345	SIGN	401	/	457	-	513	LBL 01
290	30	346	.1	402	16	458	RCL 15	514	CF 00
291	STO 06	347	*	403	+	459	1	515	"OPTION :"
292	RCL 03	348	STO 06	404	STO 09	460	-	516	AVIEW
293	STO 09	349	RDN	405	LBL 17	461	/	517	PSE
294	RCL 02	350	GTO "K"	406	LBL "N"	462	SQRT	518	"FIX "
295	.99	351	LBL 02	407	RCL IND 09	463	X<>Y	519	XEQ 44
296	/	352	FC? 05	408	1/X	464	/	520	"H ?"
297	STO 02	353	GTO "K"	409	STO 07	465	RCL 05	521	XEQ 41
298	STO 03	354	FS?C 07	410	XEQ 15	466	X<>Y	522	X=0?
299	FC? 08	355	GTO 01	411	XEQ 15	467	RTN	523	GTO C
300	STO 08	356	SF 07	412	X<>Y	468	LBL 45	524	"ENTER "
301	LBL 43	357	GTO "K"	413	-	469	X<> L	525	XEQ 44
302	FIX 1	358	LBL 01	414	RCL 07	470	XEQ 50	526	PROMPT
303	RCL 09	359	2	415	*	471	ST* L	527	STO 08
304	XEQ 30	360	ST/ 06	416	RCL 00	472	X<> L	528	XEQ 39
305	FC? 08	361	RDN	417	/	473	FIX 0	529	1
306	GTO 22	362	GTO "K"	418	FS? 10	474	"K"	530	ST- 09
307	XEQ 21	363	LBL 42	419	XEQ 18	475	ARCL 06	531	STO 06
308	GTO E	364	CLA	420	FS? 00	476	">"	532	SF 00
309	LBL 22	365	ARCL X	421	XEQ 45	477	FIX 3	533	GTO 43
310	LBL "K"	366	"H % STEP"	422	S+	478	XEQ 38	534	LBL 39
311	XEQ 21	367	AVIEW	423	ISG 09	479	CF 21	535	"DISPL. K(N) ?"
312	RCL 06	368	RTN	424	GTO "N"	480	RCL L	536	XEQ 41
313	ENTER↑	369	LBL 21	425	GTO 20	481	/	537	X=0?
314	ABS	370	STO 05	426	LBL 15	482	ISG 06	538	SF 00
315	.1	371	MEAN	427	ISG 09	483	STO X	539	RTN
316	X<>Y?	372	STO 04	428	RCL 08	484	RTN	540	LBL 44
317	SF 09	373	RCL 08	429	XEQ 16	485	LBL E	541	FS? 10
318	RDN	374	STO 03	430	RCL IND 09	486	BEEP	542	"HW"
319	XEQ 42	375	RTN	431	XEQ 16	487	SF 21	543	FC? 10
320	RDN	376	LBL 33	432	-	488	FC? 55	544	"HL"
321	%	377	STO 08	433	LN	489	GTO 01	545	"H<00>"
322	STO Z	378	RCL 09	434	RTN	490	FC? 09	546	RTN
323	+	379	1	435	LBL 16	491	XEQ 36	547	LBL 36
324	FS? 05	380	-	436	RCL 00	492	LBL 01	548	ADV
325	XEQ 34	381	GTO 30	437	Y↑X	493	FIX 2	549	ADV
326	XEQ 33	382	LBL 34	438	FC? 10	494	RCL 03	550	SF 12
327	X<=Y?	383	LBL "L"	439	RTN	495	CLA	551	"FB 6"
328	GTO 02	384	RCL 02	440	RCL 01	496	XEQ 44	552	ACA
329	FS?C 09	385	X<>Y	441	Y↑X	497	XEQ 38	553	PRBUF
330	GTO 01	386	X<>Y?	442	RTN	498	FIX 3	554	"RESULTS"
331	-2	387	RTN	443	LBL 18	499	XEQ 50	555	ACA
332	ST/ 06	388	RCL Z	444	RCL 01	500	RCL 04	556	PRBUF
333	RDN	389	2	445	1/X	501	*	557	CF 12
334	FC?C 05	390	/	446	3	502	"K (MEAN)"	558	ADV
335	SF 05	391	ENTER↑	447	/	503	XEQ 38	559	SF 09
336	GTO "K"	392	ENTER↑	448	*	504	RCL 05	560	RTN

Program Listing

(FB 6 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
561	LBL 38								
562	"F : "								
563	FS? 55								
564	GTO 01								
565	ARCL X								
566	AVIEW								
567	RTN								
568	LBL 01								
569	SF 21								
570	ACA								
571	ACX								
572	PRBUF								
573	RTN								
574	LBL 50								
575	1								
576	FS? 01								
577	RTN								
578	12								
579	FS? 03								
580	365								
581	END.								

EXAMPLE 3.6

(See also page 47 in manual)

Data from Appendix I,
Tab. 4.5

**FB 6
RESULTS**

L<00> : 19.25
K <MEAN> : 0.532
C.V. : 0.408

} **Results of step 11**

K<1.> : 0.370
K<2.> : 0.518
K<3.> : 0.385
K<4.> : 0.419
K<5.> : 0.808
K<6.> : 1.007
K<7.> : 0.405
K<8.> : 0.500
K<9.> : 0.407
K<10.> : 0.321
K<11.> : 0.707
L<00> : 19.25
K <MEAN> : 0.532
C.V. : 0.408

} **Results of step 13**

3.7: PROGRAM DESCRIPTION FB 7

Fitting Seasonally Oscillating Growth Data

Given a value of D and length-at-age data, the program estimates the values of the parameters L_{∞} , K, t_o , t_s and C of the equation

$$L_t = L_{\infty} \left(1 - e^{-\left(KD(t-t_o) + C \frac{KD}{2\pi} \sin 2\pi(t-t_s) \right)} \right)^{1/D} \quad \dots 1)$$

which is a version of the generalized VBGF suitable to describe the seasonally oscillating length-growth of fishes.

The parameter estimation is based on multiple linear regression analysis and the iterative method described in the manual, based on Pauly and Gaschütz (1979). The calculation of the regression coefficients is based on the program "Multiple Regression Analysis" No. 5058, HP 67/97 Users' Library (Europe) by Tapio Westerlund while the routine for the estimation of R^2 is based on "statistics for multiple regression analysis", No. 50585, HP 67/97 User's Library (Europe), also by T. Westerlund.

Operating Limits and Warnings

The age values must be entered in years, months or days. Seasonally oscillating growth in weight cannot be handled by this program (see Shul'man 1974 and Moreau 1985 for methods to deal with the seasonally oscillating growth in weight of fishes)

FB 7: FITTING SEASONALLY OSCILLATING GROWTH DATA

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM			* FB 7 * DATA INP.: NO. OF ROWS ?
1.	ENTER NO. OF ROWS	k	R/S	AGE INP. IN: Y/M/D ? <1,2,3>
2.	INDICATE WHETHER THE AGE INPUT IS IN YEARS ("1"), MONTHS ("2") OR DAYS ("3")	1,2 OR 3	R/S	ENTER D
3.	ENTER D	D	R/S	1. ROW: LENGTH ?
4.	ENTER FOR ROW 1, 2, 3 ... k			
4.1	LENGTH AT AGE t	L_t	R/S	AGE ?
4.2	AGE	t	R/S	2(3,4,... k) ROW: : REVIEW: YES: 1, NO: 0
5.	OPTION:			
5.1	REVIEW AND CORRECTION (SEE GENERAL INSTRUCTIONS)	1	R/S	
5.2	PROCEED	0	R/S	L<MAX>: (x) CORRECTION ? YES: 1, NO: 0
6.	VERIFY $L_{\max}$ (SEE GENERAL INSTRUCTIONS)	1	R/S	
	NO CORRECTION	0	R/S	PLEASE WAIT
7.	COMPUTATION PROCEDURE (WITH DISPLAY OF THE STEP SIZE USED BY THE ITERATION ROUTINE)			(x)% STEP
8.	DISPLAY OF RESULTS:			(RESULTS)
8.1	ASYMPTOTIC LENGTH (L_{∞})			L<00>: (x)
8.2	K (ON ANNUAL BASIS)		R/S	K : (x)
8.3	AGE AT LENGTH ZERO (IN YEARS) (t)		R/S	T<0> : (x)
8.4	AGE AT ONSET OF FIRST OSCILLATION (t_s)		R/S	T<S> : (x)

FB 7: FITTING SEASONALLY OSCILLATING GROWTH DATA

USER INSTRUCTIONS (cont.)

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
8.5	OSCILLATION AMPLITUDE (C)		R/S	C : (x)
8.6	MULTIPLE COEFFICIENT OF DETERMINATION (R^2)		R/S	R^2 : (x)
9.	TO REVIEW RESULTS, PRESS		E	(RESULTS)
10.	FOR A NEW SET OF DATA, INITIALIZE		f c	* FB 7 *

REGISTERS, STATUS, FLAGS

PROGR. NAME: FB 7 (Fitting Seasonally Oscillating Growth Data)

STATUS : REG. (PROGR.): 205
SIZE (MIN.) : (k*2)+33 SIZE (MAX.): 114

FLAGS : 1 - 4, 6, 9

ASSIGNMENTS:

A: GENERAL COMMANDS

B: SPECIAL COMMANDS

INITIALIZE : (f)c
REVIEW RESULTS : E
REVIEW DATA : D

REGISTERS :

00 :	D	21 :	[u]
01 :	[u]	22 :	[u]
02 :	L<∞> ^D	23 :	[u]
03 :	R ₂	24 :	[u]
04 :	K*D	25 :	[u]
05 :	t<o>	26 :	[u]
06 :	t<s>	27 :	[u]
07 :	C	28 :	[u]
08 :	[u]	29 :	[u]
09 :	[u]	30 :	[u]
10 :	[u]	31 :	[u]
11 :	[u]	32 :	[u]
12 :	[u]	33 :	L(1)
13 :	[u]	34 :	t(1)
14 :	[u]		.
15 :	[u]		.
16 :	[u]		.
17 :	[u]		.
18 :	[u]		L(k)
19 :	[u]		t(k)
20 :	[u]		

NOTE: "k" REPRESENTS NUMBER OF CASES (= NO. OF ROWS)

Program Listing

(FB 7)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01	LBL "FB 7"	57	LBL "P"	113	*	169	CLA	225	.99
02	LBL c	58	XEQ 11	114	"AGE :	170	GTO 07	226	/
03	CF 21	59	PROMPT	115	ARCL X	171	LBL 09	227	STO 01
04	BEEP	60	XEQ 12	116	AVIEW	172	"L<MAX>"	228	STO 02
05	" * FB 7 *"	61	PROMPT	117	PSE	173	GTO 01	229	STO 29
06	AVIEW	62	STO L	118	XEQ 13	174	LBL 11	230	XEQ "K"
07	FS? 55	63	ISG 01	119	X=0?	175	"LENGTH"	231	LBL "M"
08	XEQ "Y"	64	GTO 01	120	GTO 06	176	GTO 01	232	XEQ 10
09	CF 21	65	SF 09	121	RCL 32	177	LBL 12	233	RCL 32
10	SF 27	66	GTO 02	122	1	178	"AGE"	234	ENTER↑
11	CLRG	67	LBL 01	123	-	179	LBL 01	235	ABS
12	FIX 0	68	CLA	124	"CORR. INP. ?"	180	FC? 06	236	XEQ 15
13	10	69	ARCL 01	125	AVIEW	181	RTN	237	X>Y?
14	LBL "Q"	70	"F."	126	PSE	182	"F ?"	238	SF 09
15	CF IND X	71	XEQ 05	127	XEQ 11	183	RTN	239	RDN
16	DSE X	72	AVIEW	128	PROMPT	184	LBL 10	240	XEQ 08
17	GTO "Q"	73	LBL 02	129	STO IND Y	185	"F : "	241	RDN
18	CF 00	74	X<Y	130	RDN	186	ARCL IND X	242	%
19	"DATA INP.:"	75	RCL 29	131	1	187	AVIEW	243	STO Z
20	AVIEW	76	X<Y	132	+	188	PSE	244	+
21	PSE	77	X>Y?	133	STO 32	189	RTN	245	FS? 04
22	33	78	STO 29	134	XEQ 12	190	LBL 13	246	XEQ "U"
23	ENTER↑	79	STO IND 30	135	PROMPT	191	"CORRECTION ?"	247	XEQ "K"
24	ENTER↑	80	ISG 30	136	XEQ "T"	192	LBL 14	248	X>Y?
25	"NO. OF ROWS ?"	81	XEQ "T"	137	/	193	AVIEW	249	GTO 02
26	PROMPT	82	RCL L	138	STO IND 32	194	TONE 7	250	FS?C 09
27	STO 01	83	X<Y	139	CF 06	195	PSE	251	GTO 01
28	STO 31	84	/	140	LBL 06	196	"YES: 1, NO: 0"	252	-2
29	2	85	STO IND 30	141	"MORE "	197	PROMPT	253	ST/ 32
30	*	86	FS?C 09	142	LBL 07	198	RTN	254	RDN
31	1	87	GTO 01	143	"PREVIEW?"	199	LBL 05	255	FC?C 04
32	-	88	ISG 30	144	XEQ 14	200	"F ROW "	256	SF 04
33	+	89	GTO "R"	145	X=0?	201	FC? 06	257	GTO "M"
34	3	90	LBL 01	146	GTO "S"	202	RTN	258	LBL 01
35	10↑X	91	CF 06	147	CLA	203	"F: "	259	RCL 01
36	ST/ 01	92	CLA	148	XEQ 09	204	RTN	260	XEQ "K"
37	/	93	GTO 07	149	"F: "	205	LBL "T"	261	GTO "O"
38	+	94	LBL 0	150	FIX 2	206	FS? 01	262	LBL 02
39	STO 30	95	LBL "S"	151	ARCL 29	207	1	263	FC? 09
40	1	96	CF 06	152	AVIEW	208	FS? 02	264	GTO 02
41	ST+ 01	97	CLA	153	PSE	209	12	265	RCL 32
42	XEQ 12	98	XEQ 05	154	PSE	210	FS? 03	266	SIGN
43	"F INP. IN :"	99	"HNO. ?"	155	XEQ 13	211	365	267	XEQ 15
44	AVIEW	100	PROMPT	156	X=0?	212	RTN	268	*
45	PSE	101	2	157	GTO 01	213	LBL e	269	STO 32
46	"Y/M/D? <1,2,3>"	102	*	158	SF 06	214	CF 21	270	RDN
47	PROMPT	103	31	159	"NEW "	215	"PLEASE WAIT"	271	GTO "M"
48	SF IND X	104	+	160	XEQ 09	216	AVIEW	272	LBL 02
49	"ENTER : 0"	105	FIX 2	161	PROMPT	217	RAD	273	FC? 04
50	PROMPT	106	XEQ 11	162	STO 29	218	30	274	GTO "M"
51	STO 00	107	XEQ 10	163	CF 06	219	STO 32	275	FS?C 07
52	SF 06	108	1	164	LBL 01	220	FIX 1	276	GTO 01
53	"1."	109	+	165	"RESULTS ?"	221	50	277	SF 07
54	XEQ 05	110	STO 32	166	XEQ 14	222	RCL 29	278	GTO "M"
55	AVIEW	111	XEQ "T"	167	X=0?	223	X<Y?	279	LBL 01
56	PSE	112	RCL IND 32	168	GTO e	224	SF 06	280	2

Program Listing

(FB 7 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
281	ST/ 32	337	/	393	*	449	*	505	*
282	RDN	338	RCL 00	394	+	450	STO 28	506	ST- 21
283	GTO "M"	339	Y+X	395	RCL 18	451	RCL 11	507	RCL 28
284	LBL 10	340	-	396	RCL 24	452	*	508	RCL 11
285	STO 03	341	LN	397	*	453	ST+ 07	509	*
286	RCL 02	342	STO 27	398	+	454	RCL 28	510	ST- 22
287	STO 01	343	ST+ 12	399	RCL 15	455	RCL 10	511	RCL 27
288	RTN	344	X+2	400	+	456	*	512	RCL 11
289	LBL 08	345	ST+ 13	401	STO 09	457	ST+ 06	513	X+2
290	CLA	346	ISG 30	402	RCL 24	458	RCL 28	514	*
291	ARCL X	347	RCL IND 30	403	*	459	RCL 09	515	ST- 23
292	"F % STEP"	348	STO 24	404	X<Y	460	*	516	ISG 30
293	AVIEW	349	PI	405	STO 08	461	ST+ 05	517	GTO "W"
294	RTN	350	*	406	+	462	RCL 28	518	3
295	LBL 15	351	2	407	STO 27	463	RCL 08	519	STO 00
296	FS? 06	352	*	408	RCL 22	464	*	520	RCL 21
297	.1	353	ENTER↑	409	RCL 26	465	ST+ 04	521	RCL 18
298	FC? 06	354	SIN	410	*	466	RCL 27	522	*
299	.5	355	STO 25	411	RCL 21	467	RCL 08	523	RCL 19
300	RTN	356	RDN	412	RCL 25	468	*	524	X+2
301	LBL "U"	357	COS	413	*	469	STO 28	525	-
302	RCL 29	358	STO 26	414	+	470	RCL 08	526	STO 24
303	X<Y	359	RCL 27	415	RCL 19	471	*	527	RCL 22
304	X>Y?	360	RCL 04	416	RCL 24	472	ST- 14	528	RCL 18
305	RTN	361	RCL 05	417	*	473	RCL 28	529	*
306	RCL Z	362	RCL 24	418	+	474	RCL 09	530	RCL 20
307	2	363	*	419	RCL 16	475	*	531	RCL 19
308	/	364	+	420	+	476	ST- 15	532	*
309	ENTER↑	365	RCL 06	421	RCL 23	477	RCL 28	533	-
310	ENTER↑	366	RCL 25	422	RCL 26	478	RCL 10	534	STO 25
311	RCL 01	367	*	423	*	479	*	535	RCL 23
312	+	368	+	424	RCL 22	480	ST- 16	536	RCL 18
313	GTO "U"	369	RCL 07	425	RCL 25	481	RCL 28	537	*
314	LBL "K"	370	RCL 26	426	*	482	RCL 11	538	RCL 20
315	STO 02	371	*	427	+	483	*	539	X+2
316	RCL 30	372	+	428	RCL 20	484	ST- 17	540	-
317	FRC	373	-	429	RCL 24	485	RCL 27	541	STO 26
318	33	374	STO 28	430	*	486	RCL 09	542	RCL 18
319	+	375	RCL 17	431	+	487	*	543	RCL 16
320	STO 30	376	RCL 26	432	RCL 17	488	STO 28	544	RCL 15
321	4.028	377	*	433	+	489	RCL 09	545	RCL 12
322	0	378	RCL 16	434	STO 11	490	*	546	*
323	LBL "V"	379	RCL 25	435	RCL 26	491	ST- 18	547	RCL 05
324	STO IND Y	380	*	436	*	492	RCL 28	548	-
325	ISG Y	381	+	437	X<Y	493	RCL 10	549	STO 27
326	GTO "V"	382	RCL 15	438	STO 10	494	*	550	RDN
327	5	383	RCL 24	439	RCL 25	495	ST- 19	551	RCL 12
328	10+X	384	*	440	*	496	RCL 28	552	*
329	STO 14	385	+	441	+	497	RCL 11	553	RCL 06
330	STO 18	386	RCL 14	442	RCL 27	498	*	554	-
331	STO 21	387	+	443	+	499	ST- 20	555	*
332	STO 23	388	RCL 20	444	1	500	RCL 27	556	STO 28
333	LBL "W"	389	RCL 26	445	+	501	RCL 10	557	RCL 07
334	1	390	*	446	1/X	502	*	558	RCL 12
335	RCL IND 30	391	RCL 19	447	STO 27	503	STO 28	559	RCL 17
336	RCL 02	392	RCL 25	448	RCL 28	504	RCL 10	560	*

Program Listing

(FB 7 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
561 -		617 RCL 04		673 2		729 RCL 03			
562 RCL 18		618 RCL 12		674 *		730 "R+2"			
563 *		619 *		675 STO 29		731 CF 21			
564 RCL 27		620 RCL 11		676 /		732 XEQ 12			
565 RCL 20		621 RCL 05		677 STO 06		733 STOP			
566 *		622 *		678 RCL 29		734 GTO E			
567 +		623 +		679 *		735+LBL "X"			
568 RCL 24		624 RCL 10		680 SIN		736 "RESULTS :"			
569 *		625 RCL 06		681 RCL 04		737 ADV			
570 RCL 27		626 *		682 *		738 GTO 01			
571 RCL 19		627 +		683 1/X		739+LBL "Y"			
572 *		628 RCL 09		684 RCL 07		740 SF 21			
573 RCL 28		629 RCL 07		685 RCL 29		741 SF 12			
574 -		630 *		686 *		742+LBL 01			
575 RCL 25		631 +		687 *		743 RCL			
576 *		632 RCL 12		688 X<0?		744 PRBUF			
577 -		633 X+2		689 GTO 01		745 ADV			
578 RCL 26		634 RCL 31		690 STO 07		746 CF 12			
579 RCL 24		635 /		691 GTO E		747 RTN			
580 *		636 STO 28		692+LBL 01		748 RTN			
581 RCL 25		637 -		693 CHS		749+LBL 12			
582 X+2		638 STO 27		694 STO 07		750 "I: "			
583 -		639 RCL 13		695 .5		751 FS? 55			
584 /		640 RCL 28		696 ST+ 06		752 GTO 13			
585 STO 09		641 -		697+LBL E		753 ARCL X			
586 RCL 27		642 STO 28		698 DEG		754 RVIEW			
587 RCL 19		643 /		699 SF 21		755 RTN			
588 *		644 STO 25		700 BEEP		756+LBL 13			
589 RCL 28		645 RCL 28		701 FS? 55		757 SF 21			
590 -		646 RCL 27		702 XEQ "X"		758 RCL			
591 X<Y		647 -		703 RCL 02		759 ACX			
592 RCL 25		648 RCL 24		704 RCL 00		760 PRBUF			
593 *		649 /		705 1/X		761 .END.			
594 -		650 STO 26		706 Y+X					
595 RCL 24		651 RCL 27		707 FIX 2					
596 /		652 RCL 08		708 "L<00"					
597 STO 10		653 /		709 XEQ 12					
598 RCL 09		654 RCL 26		710 FIX 3					
599 RCL 20		655 /		711 RCL 04					
600 *		656 STO 27		712 RCL 00					
601 X<Y		657 RCL 03		713 /					
602 RCL 19		658 RCL 25		714 "K"					
603 *		659 RTN		715 XEQ 12					
604 +		660+LBL "0"		716 RCL 05					
605 RCL 27		661 RCL 04		717 SF 13					
606 +		662 RCL 05		718 "T<0"					
607 RCL 18		663 CHS		719 XEQ 12					
608 /		664 STO 04		720 RCL 06					
609 CHS		665 /		721 "T<S"					
610 STO 11		666 STO 05		722 XEQ 12					
611 RCL 31		667 RCL 07		723 CF 13					
612 RCL 08		668 RCL 06		724 FIX 2					
613 -		669 /		725 RCL 07					
614 1		670 CHS		726 "C"					
615 -		671 ATAN		727 XEQ 12					
616 STO 24		672 PI		728 FIX 3					

EXAMPLE 3.7

(See also page 48 in manual)

Data from Appendix I,
Tab. 4.7

* FB 7 *

RESULTS :

L(00): 32.86

K: 0.617

t(s): -0.991

t(s): 0.253

C: 0.69

Rt2: 0.999

3.8: PROGRAM DESCRIPTION FB 8

Seasonal Growth from Tagging Data

A multiple regression of the form

$$Y = a + b_1 X_1 + b_2 X_2 \quad \dots 1)$$

is used to estimate the parameters L_{∞} and K of the VBGF. The following definitions apply

$$Y = (L_2^D - L_1^D) / (t_2 - t_1)$$

and $X_1 = \bar{L} = (L_1^D + L_2^D) / 2$

where L_1 and L_2 are the length at tagging and at recapture, respectively, corresponding to the times t_1 and t_2 , while X_2 is the average water temperature ($\bar{T}$) while a given fish was at large. Thus, given a series of L_1 and L_2 data, of the times at large and their corresponding temperatures, the growth parameters can be estimated from

$$L_{\infty} = \left[\frac{a + (b_2 \bar{T})}{-b_1} \right]^{1/D} \quad \dots 2)$$

and

$$K = -b_1 / D \quad \dots 3)$$

and

$$C = (b_2 (T_s - T_w)) / 2 (a + (b_2 \bar{T})) \quad \dots 4)$$

where T_s is the highest (summer) and T_w the lowest (winter) mean monthly^s temperatures in the water body in^w question, while $\bar{T}$ is the mean annual temperature.

In analogy to the "forced Gulland and Holt Plot" (see Program FB5), a forcing value of $L_{(\infty)}$ can be used in conjunction with equation (2), which allows for K to be estimated even when the fish used represented a narrow range of lengths only.

Operating Limits and Warnings

1) A value of D must be entered, i.e., $D = 1$ when the special VBGF is used, and $D < 1$ when the generalized VBGF is used.

2) The values of L_{∞} , K and C obtained by this method are approximate and should be confirmed whenever possible, using other methods.

FB 8: SEASONAL GROWTH FROM TAGGING DATA

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM			* FB 8 *
1.	DISPLAY OF MENU			MENU
1.1	DATA INPUT			DATA INP. : A
1.2	COMPUTATION OF GROWTH PARAMETERS			GROWTH P. : H OSC. AMPL.: I
1.3	COMPUTATION OF C			
1.4	COMPUTATION OF K WITH FIXED L ∞			L<00> SET : J
1.5	{			MENU : C
1.6	{ SEE GENERAL			INIT. : c
1.7	{ INSTRUCTIONS			REV. INP. : D
1.8	{			REV. RES. : E
2.	ENTER DATA		A	DATA INP.: NO. OF ROWS ?
2.1	NO. OF ROWS	k	R/S	TIME INP. IN: Y/M/D: (1,2,3)
2.2	INDICATE WHETHER THE TIME INPUT IS IN YEARS ("1"), MONTHS ("2") OR DAYS ("3")	1,2 OR 3	R/S	ENTER: D
2.3	ENTER D	D	R/S	1. ROW: L<1> ?
2.4	ENTR FOR ROW 1, 2, ... k			
2.4.1	LENGTH AT t_1	L_1	R/S	L<2> ?
2.4.2	LENGTH AT t_2	L_2	R/S	T<2>-T<1> ?
2.4.3	TIME AT LARGE	Δt	R/S	TEMP. ?
2.4.4	MEAN WATER TEMPERATURE DURING TIME Δt	T	R/S	2(3.,4.,.k) ROW:
3.	BEFORE ENTERING DATA, PRECEDING INPUT CAN BE REVIEWED (SEE GENERAL INSTRUCTIONS)		D	LAST INPUT: PLEASE WAIT
4.	DISPLAY OF RESULTS			RESULTS:
4.1.1	MULTIPLE COEFFICIENT OF DETERMINATION			R^2 : (x)
4.1.2	INTERCEPT a OF REGR.		R/S	a : (x)
4.1.3	PARTIAL REGRESSION COEFFICIENT b_1		R/S	b<1> : (x)
4.1.4	PARTIAL REGRESSION COEFFICIENT b_2		R/S	B<2> : (x)

FB 8: SEASONAL GROWTH FROM TAGGING DATA

USER INSTRUCTIONS (cont.)

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
4.1.5	PARTIAL CORRELATION COEFFICIENT ($\Delta L/\Delta t$ vs L)		R/S	r<Y1.2> : (x)
4.1.6	PARTIAL CORRELATION COEFFICIENT ($\Delta L/\Delta t$ vs T)		R/S	r<Y2.1> : (x)
5.	TO REVIEW RESULTS, PRESS		E	(RESULTS)
6.	SELECT ANY OF THE SUB-PROGRAMS SUB-PROGRAMS:			
6.1	ESTIMATION OF GROWTH PARAMETERS		H	GROWTH PARAM. ENTER TEMP.:
6.1.1	ENTER MEAN ANNUAL WATER TEMPERATURE	$\bar{T}$	R/S	
6.1.2	RESULT: ASYMPTOTIC LENGTH K (ON AN ANNUAL BASIS)		R/S	L<00>: (x) K : (x)
6.2	ESTIMATION OF AMPLITUDE OF SEASONAL GROWTH OSCILLATION (C)		I	OSCILL. AMPL. ENTER T<S>
6.2.1	ENTER HIGHEST MEAN MONTHLY TEMPERATURE	T_s	R/S	ENTER T<W>
6.2.2	ENTER LOWEST MEAN MONTHLY TEMPERATURE	T_w	R/S	ENTER TEMP.
6.2.3	ENTER MEAN ANNUAL WATER TEMPERATURE	$\bar{T}$	R/S	C : (x)
6.3	ESTIMATION OF K BASED ON FORCING VALUE OF L_∞		J	L<00> SET ENTER L<00> ENTER TEMP.
6.3.1	ENTER ASYMPTOTIC LENGTH	L_∞	R/S	
6.3.2	ENTER MEAN ANNUAL WATER TEMPERATURE	$\bar{T}$	R/S	K : (x)
7.	FOR A NEW SET OF DATA, INITIALIZE		f c	* FB 8 *

REGISTERS, STATUS, FLAGS

PROGR. NAME: FB 8 (Seasonal Growth from Tagging Data)

STATUS : REG. (PROGR.): 188
 SIZE (MIN.) : 024 SIZE (MAX.): -

FLAGS : 1 - 3, 8

ASSIGNMENTS:

A: GENERAL COMMANDS

B: SPECIAL COMMANDS

INITIALIZE : (f)c
 REVIEW RESULTS : E
 RECALL MENU : C
 REVIEW DATA : D

DATA INPUT : A
 COMP. OF GROWTH PARA. : H
 COMP. OF OSCILL. AMPL.: I
 "K" FROM SET L<oo> : J

REGISTERS :

SUB-

PROGR.:	A	H	I	J
00 :	D	RESULTS ARE STORED IN X-REGISTER^{a)}		
01 :	a			
02 :	r<y1.2>			
03 :	r<y2.1>			
04 :	[u]			
05 :	[u]			
06 :	[u]			
07 :	R ₂			
08 :	b ₁			
09 :	b ₂			
10 :	[u]			
11 :	[u]			
12 :	[u]			
13 :	[u]			
14 :	[u]			
15 :	[u]			
16 :	[u]			
17 :	[u]			
18 :	[u]			
19 :	[u]			
20 :	[u]			
21 :	[u]			
22 :	[u]			
23 :	[u]			

a) IF A PRINTER IS CONNECTED, RESULTS CAN BE REVIEWED VIA RCL 05

Program Listing

(FB 8)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01	LBL "FB 8"	57	AVIEW	113	RCL 05	169	GTO 01	225	ST* 01
02	LBL C	58	PSE	114	RCL 01	170	DSE 09	226	STO 08
03	CF 21	59	PSE	115	RCL 02	171	LBL "Y"	227	RCL 18
04	BEEP	60	"NO. OF ROWS ?"	116	+	172	XEQ 07	228	RCL 10
05	" * FB 8 *"	61	PROMPT	117	2	173	XEQ 10	229	RCL 16
06	XEQ "Q"	62	3	118	/	174	STO 23	230	*
07	SF 27	63	10+X	119	STO 04	175	X<>Y	231	XEQ 04
08	10	64	/	120	Σ+	176	STO 22	232	STO 05
09	LBL "M"	65	1	121	RCL 06	177	X<> Z	233	ST* 08
10	CF IND X	66	+	122	ST+ 16	178	STO 21	234	RCL 19
11	DSE X	67	STO 09	123	X+2	179	X<> T	235	RCL 12
12	GTO "M"	68	"TIME INP. IN :"	124	ST+ 17	180	STO 20	236	RCL 16
13	CF 00	69	AVIEW	125	RCL 06	181	ISG 09	237	*
14	CLRG	70	PSE	126	RCL 04	182	LBL 01	238	XEQ 04
15	SREG 10	71	"Y/M/D? <1,2,3>"	127	*	183	FC? 06	239	STO 06
16	LBL C	72	PROMPT	128	ST+ 18	184	XEQ 07	240	ST* 09
17	"MENU :"	73	SF IND X	129	RCL 06	185	GTO "R"	241	RCL 14
18	AVIEW	74	"ENTER : D"	130	RCL 05	186	LBL 10	242	RCL 10
19	PSE	75	PROMPT	131	*	187	TONE 7	243	RCL 12
20	"DATA INP.: A"	76	STO 00	132	ST+ 19	188	"L<1> ?"	244	*
21	AVIEW	77	GTO "Y"	133	FS? 06	189	PROMPT	245	XEQ 04
22	PSE	78	LBL "R"	134	GTO 04	190	"L<2> ?"	246	STO 04
23	PSE	79	FC? 06	135	FC? 09	191	PROMPT	247	X+2
24	"GROWTH P.: H"	80	XEQ 10	136	GTO "R"	192	"T<2>-T<1> ?"	248	ST- 01
25	AVIEW	81	X<> 23	137	SF 06	193	PROMPT	249	RCL 04
26	PSE	82	STO 05	138	LBL D	194	"TEMP. ?"	250	RCL 05
27	PSE	83	RDN	139	"LAST INPUT :"	195	PROMPT	251	*
28	"OSC. AMPL.: I"	84	X<> 22	140	AVIEW	196	RTN	252	ST- 09
29	AVIEW	85	STO 03	141	PSE	197	LBL 14	253	RCL 01
30	PSE	86	RDN	142	20	198	AVIEW	254	ST/ 09
31	PSE	87	X<> 21	143	1	199	TONE 7	255	RCL 04
32	"L<00> SET : J"	88	STO 02	144	XEQ 01	200	PSE	256	RCL 06
33	AVIEW	89	X<>Y	145	2	201	"YES: 1, NO: 0"	257	*
34	PSE	90	X<> 20	146	XEQ 01	202	PROMPT	258	ST- 08
35	PSE	91	STO 01	147	"dT"	203	RTN	259	RCL 01
36	"MENU : C"	92	FS? 06	148	XEQ 02	204	LBL 07	260	ST/ 08
37	AVIEW	93	GTO 02	149	"TEMP."	205	FIX 0	261	RCL 08
38	PSE	94	ISG 09	150	XEQ 02	206	CLA	262	RCL 05
39	"INIT.: c"	95	GTO 01	151	GTO 03	207	ARCL 09	263	*
40	AVIEW	96	SF 09	152	LBL 01	208	"F. ROW :"	264	RCL 09
41	PSE	97	GTO 02	153	FIX 0	209	AVIEW	265	RCL 06
42	"REV. INP.: D"	98	LBL 01	154	"L<"	210	PSE	266	*
43	AVIEW	99	XEQ 07	155	ARCL X	211	RTN	267	+
44	PSE	100	LBL 02	156	"F>"	212	LBL 04	268	RCL 17
45	PSE	101	RCL 02	157	X<>Y	213	"PLEASE WAIT"	269	RCL 16
46	"REV. RES.: E"	102	RCL 00	158	LBL 02	214	AVIEW	270	XEQ 03
47	PROMPT	103	Y+X	159	FIX 2	215	RCL 11	271	STO 01
48	GTO C	104	STO 02	160	XEQ "P"	216	RCL 10	272	/
49	LBL H	105	RCL 01	161	1	217	XEQ 03	273	STO 07
50	GTO "U"	106	RCL 00	162	+	218	STO 02	274	RCL 04
51	LBL I	107	Y+X	163	PSE	219	STO 01	275	RCL 02
52	GTO "V"	108	STO 01	164	RTN	220	STO 09	276	RCL 03
53	LBL J	109	-	165	LBL 03	221	RCL 13	277	*
54	GTO "W"	110	RCL 03	166	"CORRECTION ?"	222	RCL 12	278	SQRT
55	LBL A	111	/	167	XEQ 14	223	XEQ 03	279	/
56	"DATA INP.:"	112	STO 06	168	X=0?	224	STO 03	280	STO 04

Program Listing

(FB 8 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
281	RCL 05	337	XEQ 04	393	"b(2)"	449	STO 06	505	RTN
282	RCL 01	338	STO 01	394	9	450	XEQ 07	506	"FOR "
283	RCL 02	339	GTO 06	395	XEQ "X"	451	RCL 05	507	ARCL Y
284	*	340	LBL 03	396	ADV	452	RCL 09	508	5
285	SORT	341	X12	397	2	453	*	509	SF 21
286	/	342	LBL 04	398	"R(Y1.2)"	454	RCL 01	510	GTO "X"
287	STO 05	343	RCL 15	399	XEQ "P"	455	+	511	LBL 00
288	RCL 06	344	/	400	3	456	2	512	FC? 55
289	RCL 01	345	-	401	"R(Y2.1)"	457	*	513	GTO 01
290	RCL 03	346	RTN	402	XEQ "P"	458	1/X	514	STO 05
291	*	347	LBL 06	403	CF 13	459	RCL 04	515	SF 21
292	SORT	348	FIX 3	404	ADV	460	RCL 06	516	5
293	/	349	FS? 55	405	ADV	461	-	517	XEQ "X"
294	STO 06	350	GTO 02	406	CF 21	462	RCL 09	518	FC? 08
295	RCL 04	351	BEEP	407	LBL 03	463	*	519	ADV
296	*	352	LBL E	408	SF 05	464	*	520	CF 21
297	-	353	FS? 05	409	GTO C	465	FIX 3	521	"H "
298	1	354	SF 07	410	LBL H	466	"C"	522	GTO 02
299	RCL 04	355	"R12"	411	LBL "U"	467	GTO 00	523	LBL 01
300	X12	356	7	412	"GROWTH PARAM."	468	LBL J	524	"H "
301	-	357	XEQ 01	413	XEQ "T"	469	LBL "W"	525	LBL 02
302	1	358	"a"	414	XEQ 07	470	"L(00) SET"	526	ARCL X
303	RCL 06	359	1	415	RCL 09	471	XEQ "T"	527	FC? 55
304	X12	360	XEQ 01	416	*	472	"L(00)"	528	PROMPT
305	-	361	"b(1)"	417	RCL 01	473	XEQ 09	529	FS?C 08
306	*	362	8	418	+	474	RCL 05	530	RTN
307	SORT	363	XEQ 01	419	RCL 08	475	STO 04	531	GTO C
308	/	364	"b(2)"	420	CHS	476	XEQ 07	532	LBL "N"
309	STO 02	365	9	421	/	477	RCL 05	533	FS? 01
310	RCL 06	366	XEQ 01	422	RCL 00	478	RCL 09	534	1
311	RCL 04	367	"R(Y1.2)"	423	1/X	479	*	535	FS? 02
312	RCL 05	368	2	424	Y1X	480	RCL 01	536	12
313	*	369	XEQ 01	425	SF 08	481	+	537	FS? 03
314	-	370	"R(Y2.1)"	426	FIX 2	482	RCL 04	538	365
315	1	371	3	427	"L(00)"	483	/	539	RTN
316	RCL 04	372	XEQ 01	428	XEQ 08	484	RCL 00	540	LBL "P"
317	X12	373	GTO 03	429	RCL 06	485	1/X	541	"H . . ."
318	-	374	LBL 01	430	CHS	486	Y1X	542	ARCL IND X
319	1	375	XEQ "P"	431	RCL 00	487	RCL 00	543	AVIEW
320	RCL 05	376	FC? 07	432	/	488	/	544	RTN
321	X12	377	STOP	433	XEQ "H"	489	XEQ "W"	545	LBL "X"
322	-	378	RTN	434	*	490	*	546	"H ."
323	*	379	LBL 02	435	FIX 3	491	FIX 3	547	ACA
324	SORT	380	XEQ "S"	436	"K"	492	"K"	548	RCL IND X
325	/	381	SF 21	437	GTO 08	493	GTO 08	549	ACX
326	STO 03	382	ADV	438	LBL I	494	LBL 07	550	PRBUF
327	RCL 16	383	7	439	LBL "V"	495	"TEMP."	551	RTN
328	RCL 15	384	"R12 "	440	"OSCILL. AMPL."	496	LBL 09	552	LBL "Q"
329	/	385	XEQ "X"	441	XEQ "T"	497	FIX 2	553	AVIEW
330	RCL 00	386	SF 13	442	"T(S)"	498	PSE	554	PSE
331	RCL 10	387	1	443	XEQ 09	499	ASTO X	555	FC? 55
332	*	388	"a "	444	RCL 05	500	"ENTER "	556	RTN
333	XEQ 04	389	XEQ "X"	445	STO 04	501	ARCL X	557	SF 21
334	RCL 09	390	8	446	"T(W)"	502	PROMPT	558	ADV
335	RCL 12	391	"b(1)"	447	XEQ 09	503	STO 05	559	ADV
336	*	392	XEQ "X"	448	RCL 05	504	FC? 55	560	SF 12

Program Listing

(FB 8 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
561	GTO 01								
562	LBL "S"								
563	"RESULTS :"								
564	BEEP								
565	LBL "T"								
566	AVIEW								
567	FC? 55								
568	RTN								
569	SF 21								
570	ADV								
571	LBL 01								
572	ACA								
573	PRBUF								
574	CF 12								
575	CF 21								
576	.END.								

EXAMPLE 3.8

(See also page 49 in manual)

Data from Appendix I,
Tab. 4.5

* FB 8 *

RESULTS :

R12 : 0.648
a : -0.065
b(1) : -0.001
b(2) : 0.003

r(y1.2) : -0.722
r(y2.1) : 0.549

GROWTH PARAM.
FOR TEMP. : 28.50
L(00) : 22.08
K : 0.387

OSCILL. AMPL.
FOR T(S) : 29.40
FOR T(W) : 27.20
FOR TEMP. : 28.50
C : 0.146

L(00) SET
FOR L(00) : 28.40
FOR TEMP. : 28.50
K : 0.419

3.9: PROGRAM DESCRIPTION FB 9

Generalized VBGF and Derivatives: Solutions

The generalized von Bertalanffy Growth Formula (VBGF) has for length the form

$$L_t = L_{\infty} (1 - e^{-KD(t-t_o)})^{1/D} \quad \dots 1)$$

and its derivative is

$$dL/dt = L_{\infty} (1 - e^{-KD(t-t_o)})^{1/D-1} K e^{-KD(t-t_o)} \quad \dots 2)$$

when $D < 1$, there is an inflexion (t_i) point at age

$$t_i = t_o - \frac{\ln D}{KD} \quad \dots 3)$$

and at length

$$L_i = L_{\infty} (1 - e^{(\ln D)})^{1/D} \quad \dots 4)$$

The generalized VBGF for weight is

$$W_t = W_{\infty} (1 - e^{-KD(t-t_o)})^{b/D} \quad \dots 5)$$

the first derivative of which is

$$dW/dt = W_{\infty} bK (1 - e^{-KD(t-t_o)})^{b/D-1} e^{-KD(t-t_o)} \quad \dots 6)$$

the weight at the inflexion point being given by

$$W_i = W_{\infty} \left(\frac{b-D}{b}\right)^{b/D} \quad \dots 7)$$

Equations (1) and (5) correspond to the normal, or "special" VBGF when $D = 1$ and $b = 3$.

When growth in length oscillates seasonally, length at age is given by

$$L_t = L_{\infty} (1 - e^{-(KD(t-t_o) + \frac{C KD}{2\pi} \sin 2\pi(t-t_s))})^{1/D} \quad \dots 8)$$

For equations describing seasonally oscillating growth in weight see Shul'man (1975) and Moreau (1985).

Operating Limits and Warnings

- 1) Equations (3) and (4) have no solutions when $D = 1$.
- 2) L_t and W_t must always be lower than L_{∞} and W_{∞} , respectively.

FB 9: GENERALIZED VBGF AND DERIVATIVES: SOLUTIONS

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM			* FB 9 * SIZE INPUT: SELECT: LENGTH: 1 WEIGHT: 2 ENTER CONST.:
1.	<u>SIZE INPUT: LENGTH</u>	1	R/S	L<00> ?
1.1	ENTER CONSTANTS:			K<YR> ?
1.1.1	ASYMPTOTIC LENGTH	L	R/S	T<0> ?
1.1.2	K (ON AN ANNUAL BASIS)	k [∞]	R/S	
1.1.3	OPTION:			
1.1.3.1	ENTER t ₀ IF AVAILABLE (ON AN ANNUAL BASIS)	t ₀	R/S	D ?
1.1.3.2	IF t ₀ IS NOT KNOWN, BUT IS TO BE COMPUTED BY SUB- PROGRAM H, SIMPLY PRESS		R/S	D ?
1.1.4	ENTER D	D	R/S	SEAS. OSCILL. ? YES: 1, NO: 0
1.2	INDICATE WHETHER YOU WANT ("1") OR DO NOT WANT ("0") TO HAVE SEASONAL OSCILLATING GROWTH BEING CONSIDERED WHEN COMPUTING LENGTH AT A GIVEN AGE (SUB- PROGRAM "A")			
1.2.1	IF YES, ENTER	1	R/S	C ?
1.2.1.1	ENTER	C	R/S	T<S>
1.2.1.2	ENTER	t _s	R/S	AGE INPUT IN: Y/M/D: <1,2,3>
1.2.2	IF NOT, ENTER	0	R/S	:
1.3	INDICATE WHETHER YOUR AGE INPUT IS IN YEARS ("1"), MONTHS ("2") OR DAYS ("3")	1,2 OR 3	R/S	:
1.4	DISPLAY OF MENU			MENU
1.4.1	SIZE AT GIVEN AGE (S = L OR W)			SIZE/AGE : A
1.4.2	AGE AT GIVEN SIZE			AGE/SIZE : B
1.4.3	SIZE AT INFLEXION POINT			SIZE/INFL. P.: F
1.4.4	GROWTH RATE AT GIVEN SIZE			GROWTH RATE : G
1.4.5	t ₀ FOR GIVEN SIZE AND AGE			T<0>/S+AGE : H

FB 9: GENERALIZED VBGF AND DERIVATIVES: SOLUTIONS

USER INSTRUCTIONS (cont.)

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
1.4.6	ESTIMATES OF d AND D FROM W			ESTIM. $d+D$: I
1.4.7	INITIALIZE ^{max}			INITIAL. : c
1.4.8	REVIEW MENU			MENU : C
1.5	TO OBTAIN LENGTH AT A GIVEN AGE, PRESS		A	AGE ?
	AND ENTER AGE	t	R/S	L <T>: (x)
1.6	TO OBTAIN AGE AT GIVEN LENGTH, PRESS		B	L <T> ?
	AND ENTER LENGTH	L_t	R/S	AGE: (x) ^{a)}
1.7	LENGTH AT INFLEXION POINT OF CURVE		F	L >INFL.<: (x)
	NOTE: IF $D=1$, AN ERROR MESSAGE WILL APPEAR. AND YOU WILL BE BROUGHT BACK TO THE MENU.			
1.8	TO OBTAIN GROWTH RATE AT GIVEN LENGTH, PRESS		G	LT ?
	AND ENTER LENGTH	L_t	R/S	dL/dT: (x)
1.9	TO OBTAIN t FOR GIVEN LENGTH AND AGE, PRESS		H	LT ?
1.9.1	ENTER LENGTH	L_t	R/S	AGE ?
1.9.2	ENTER AGE	t	R/S	T<O>: (x)
1.9.3	TO CONTINUE, PRESS		R/S	MORE ? 1/0
1.9.4	OPTION:			
1.9.4.1	COMPUTE MORE t VALUES	1	R/S	L<T>?
1.9.4.2	COMPUTE A MEAN ^o t FROM THE PRECEDING t -VALUES	0	R/S	MEAN T<O>: (x)
	NOTE:			
	1. IF YOU WANT TO INCLUDE ADDITIONAL t VALUES FOR THE COMPUTATION OF THE MEAN t , CONTINUE WITH			
	AND ENTER MORE LENGTH/AGE DATA PAIRS.		R/S	L<T>?

a) EXPRESSED IN THE UNIT SELECTED AT STEP 1.3

FB 9: GENERALIZED VBGF AND DERIVATIVES: SOLUTIONS

USER INSTRUCTIONS (cont.)

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
	2. IF YOU WANT TO START WITH A NEW LENGTH/AGE DATA SET, CONTINUE BY PRESSING AND ENTER FIRST LENGTH/AGE DATA PAIR		H	L<T>?
	3. WHENEVER A MEAN t IS COMPUTED, THE RESULT IS STORED AS THE t CONSTANT FOR USE WITH OTHER SUB-PROGRAMS.			
	4. IRRESPECTIVE OF THE FORM OF AGE INPUT, t IS ALWAYS EXPRESSED IN YEARS			
2.	SIZE INPUT: WEIGHT		2	ENTER CONST.:
2.1	ENTER CONSTANTS:			W<00>?
2.1.1	ASYMPTOTIC WEIGHT	W	R/S	K<YR>?
2.1.2	K (ON YEAR BASE)	k	R/S	T<0>?
2.1.3	t (FOR OPTIONS SEE 1.1.3)	t	R/S	D ?
2.1.4	D^0	D^0	R/S	b* ?
2.1.5	EXPONENT OF L/W RELATIONSHIP	b	R/S	AGE INPUT IN: Y/M/D: (1,2,3)
2.2	ALL FURTHER PROCEDURE ARE			
.	SIMILAR TO STEP 1.3-1.9			
.	USING WEIGHT INSTEAD OF			
.	LENGTH (NOTE THAT USING D=1			
.	IN SUB-PROGRAM "F" IS OK)			
2.9	SPECIAL SUB-PROGRAM:			
	ESTIMATE d AND D FROM W_{max}		I	W<max> ?
	ENTER W_{max} IN GRAM	W_{max}	R/S	d: (x) D: (x)
	<u>GENERAL INSTRUCTIONS FOR THE USE OF SUB-PROGRAMS:</u>			
1.	UPON CALLING A SUB-PROGRAM VIA LABEL KEY A, B, F, G, H OR I YOU WILL SEE FIRST THE SUBPROGRAM TITLE, THEN THE CONTENT OF THE X-REGISTER FOLLOWED BY AN INPUT REQUEST			

FB 9: GENERALIZED VBGF AND DERIVATIVES: SOLUTIONS

USER INSTRUCTIONS (cont.)

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
	(THE FIRST TWO STEPS HAVE BEEN OMITTED IN THE USER INSTRUCTIONS)			
2.	AFTER DISPLAY OF RESULTS, PRESSING "R/S" BRINGS YOU BACK TO THE INPUT REQUEST OF THE CURRENT SUB-PROGRAM.			
3.	TO CHANGE TO ANOTHER SUB-PROGRAM, PRESS THE CORRESPONDING LABEL KEY.			
4.	THE RESULT OF ONE SUB-PROGRAM CAN BE USED AS INPUT FOR ANOTHER SUBPROGRAM WITHOUT HAVING TO ENTER THE VALUE AGAIN. EXAMPLE: WHAT IS THE GROWTH RATE AT AGE $t=2$? PROCEDURE (ASSUMING THAT ALL CONSTANTS HAVE BEEN ENTERED, "LENGTH-MODE")			
4.1	SELECT SUB-PROGRAM "A"		A	SIZE/AGE AGE ?
4.2	ENTER AGE ($t=2$)	2	R/S	L<T>: (x)
4.3	SELECT SUB-PROGRAM "G" (DISPLAY OF RESULT FROM SUB-PROGRAM "A")		G	GROWTH R. L<T> ?
4.4	YOUR L _t IS ALREADY STORED IN THE X-REGISTER. SO DON'T ENTER ANYTHING, SIMPLY PRESS WHICH IS THE GROWTH RATE AT THE LENGTH CORRESPONDING TO AGE $t=2$		R/S	dL/dT: (x)
5.	TO CHANGE SELECTED OPTIONS AND/OR CONSTANTS, INITIALIZE BY PRESSING		f c	SIZE INPUT:
6.	TO REVIEW MENU, PRESS		C	MENU:

REGISTERS, STATUS, FLAGS

PROGR. NAME: FB 9 (Gener. VBGF and Derivat.: Solutions)

STATUS : REG. (PROGR.): 191
 SIZE (MIN.) : 014 SIZE (MAX.): -

FLAGS : 0 - 5, 9

ASSIGNMENTS:

A: GENERAL COMMANDS

INITIALIZE : (f)c
 RECALL MENU : C

B: SPECIAL COMMANDS

SIZE AT GIVEN AGE : A
 AGE AT GIVEN SIZE : B
 SIZE AT INFLEXION PT. : F
 GROWTH RATE AT G. SIZE: G
 t<o> AT G. SIZE + AGE : H
 d AND D FROM W<max> : I

REGISTERS :

SUB-
 PROGR.:

A B F G H I

00 :	D	
01 :	L< ∞ >	RESULTS
02 :	W< ∞ >	ARE
03 :	K	STORED
04 :	t<o>	IN
05 :	b*	X-REGISTER
06 :	C	
07 :	t<s>	
08 :	[u]	
09 :	[u]	
10 :	[u]	
11 :	[u]	
12 :	[u]	
13 :	[u]	

Program Listing

(FB 9)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01	LBL "FB 9"	57	STO 04	113	LBL 00	169	AVIEW	225	FIX 2
02	BEEP	58	CF 13	114	CLA	170	PSE	226	22
03	CF 21	59	"D"	115	ARCL IND X	171	XEQ 22	227	XEQ "0"
04	" * FB 9 *"	60	FIX 2	116	SF 21	172	"F : B"	228	LBL "L"
05	AVIEW	61	XEQ 06	117	ADV	173	AVIEW	229	XEQ "X"
06	PSE	62	STO 00	118	GTO 01	174	PSE	230	"F <T> ?"
07	SF 27	63	FS? 01	119	LBL 02	175	XEQ 25	231	XEQ "Y"
08	FC? 55	64	GTO 09	120	SF 21	176	"F : F"	232	XEQ 09
09	GTO C	65	"b*"	121	"CONSTANTS :"	177	AVIEW	233	RCL 04
10	SF 21	66	XEQ 07	122	LBL 01	178	PSE	234	+
11	SF 12	67	STO 05	123	ACA	179	XEQ 26	235	XEQ 50
12	XEQ 01	68	LBL 09	124	PRBUF	180	"F : C"	236	*
13	LBL C	69	RCL 00	125	ADV	181	AVIEW	237	XEQ "R"
14	"SIZE INPUT "	70	RCL 03	126	CF 12	182	PSE	238	"F : "
15	AVIEW	71	*	127	CF 21	183	XEQ 24	239	XEQ "Z"
16	CLRG	72	STO 06	128	RTN	184	"F : H"	240	GTO "L"
17	10	73	RCL 00	129	LBL 06	185	AVIEW	241	LBL I
18	LBL "M"	74	1/X	130	FS? 55	186	PSE	242	FS? 02
19	CF IND X	75	STO 09	131	"F "	187	XEQ 23	243	GTO 01
20	DSE X	76	FS? 01	132	LBL 07	188	"F : I"	244	"ERROR :"
21	GTO "M"	77	GTO 11	133	FS? 55	189	AVIEW	245	AVIEW
22	CF 00	78	RCL 05	134	"F "	190	PSE	246	PSE
23	TONE 7	79	*	135	LBL 08	191	"INITIAL. : C"	247	"NO HT. DATA"
24	"SELECT "	80	STO 12	136	FS? 55	192	AVIEW	248	AVIEW
25	AVIEW	81	1/X	137	"F "	193	PSE	249	PSE
26	PSE	82	STO 11	138	LBL 03	194	PSE	250	GTO C
27	"LENGTH : 1"	83	GTO 10	139	FS? 55	195	"MENU : C"	251	LBL 01
28	ASTO 01	84	LBL 11	140	XEQ 04	196	PROMPT	252	FIX 2
29	AVIEW	85	"SERGS. OSCILL.?"	141	"F ?"	197	GTO C	253	23
30	PSE	86	TONE 7	142	CF 22	198	LBL A	254	XEQ "0"
31	"WEIGHT : 2"	87	AVIEW	143	PROMPT	199	FIX 2	255	LBL "S"
32	ASTO 02	88	PSE	144	FS? 55	200	21	256	"W >MAX< ?"
33	PROMPT	89	"YES: 1, NO. 0"	145	XEQ 05	201	XEQ "0"	257	XEQ "Y"
34	SF IND X	90	PROMPT	146	RTN	202	LBL "K"	258	LOG
35	FS? 55	91	X=0?	147	LBL 04	203	XEQ "W"	259	.03574
36	XEQ 00	92	GTO 10	148	SF 21	204	STO 13	260	*
37	"ENTER CONST.:"	93	SF 00	149	ACA	205	RCL 04	261	.6742
38	AVIEW	94	"C"	150	CF 21	206	-	262	+
39	FS? 55	95	FIX 3	151	RTN	207	FS? 00	263	FIX 3
40	XEQ 02	96	XEQ 06	152	LBL 05	208	SF 09	264	"d : "
41	PSE	97	STO 06	153	SF 21	209	XEQ 10	265	XEQ "Z"
42	XEQ "X"	98	SF 13	154	CLA	210	FS? 01	266	PSE
43	"F>00<"	99	"T<S)"	155	"F : "	211	RCL 09	267	3
44	FIX 2	100	XEQ 00	156	ACA	212	FS? 02	268	*
45	XEQ 03	101	CF 13	157	FS? 22	213	RCL 12	269	CHS
46	FS? 01	102	STO 07	158	ACX	214	Y+X	270	3
47	STO 01	103	LBL 10	159	PRBUF	215	FS? 01	271	+
48	STO 02	104	"AGE INPUT IN:"	160	CF 21	216	RCL 01	272	"D : "
49	"K<VR)"	105	AVIEW	161	RTN	217	FS? 02	273	XEQ "Z"
50	FIX 3	106	PSE	162	LBL C	218	RCL 02	274	GTO "S"
51	XEQ 03	107	"Y/M/D : <1,2,3)"	163	BEEP	219	*	275	LBL H
52	STO 03	108	PROMPT	164	CF 21	220	XEQ "X"	276	0
53	SF 13	109	2	165	"MENU :"	221	"F <T> : "	277	STO 13
54	CF 22	110	+	166	AVIEW	222	XEQ "Z"	278	STO 10
55	"T<0)"	111	SF IND X	167	XEQ 21	223	GTO "K"	279	CF 13
56	XEQ 00	112	GTO C	168	"F : A"	224	LBL B	280	24

Program Listing

(FB 9 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
281	XEQ "0"	337	TONE 7	393	RCL 03	449	PI	505	XEQ 01
282	LBL "Q"	338	"ERROR : D =1"	394	*	450	*	506	"I?"
283	FIX 2	339	AVIEW	395	XEQ 50	451	2	507	XEQ "Y"
284	CF 13	340	PSE	396	/	452	*	508	XEQ 50
285	XEQ "X"	341	PSE	397	GTO 02	453	SIN	509	/
286	"T <T> ?"	342	GTO C	398	LBL 01	454	RCL 08	510	RTN
287	XEQ "Y"	343	LBL 01	399	RCL 03	455	*	511	LBL "R"
288	XEQ "W"	344	I	400	*	456	PI	512	LBL 01
289	X<Y	345	RCL 00	401	RCL 05	457	2	513	"AGE "
290	XEQ 09	346	-	402	*	458	*	514	RTN
291	-	347	RCL 09	403	RCL 02	459	/	515	LBL 21
292	SF 13	348	YIX	404	*	460	RCL 06	516	"SIZE/AGE"
293	FIX 3	349	RCL 01	405	LBL 02	461	*	517	RTN
294	"T<0> : "	350	*	406	"d"	462	+	518	LBL 22
295	XEQ "Z"	351	GTO 01	407	FS? 01	463	DEG	519	"AGE/SIZE"
296	CF 13	352	LBL 02	408	"L"	464	RTN	520	RTN
297	ST+ 13	353	RCL 05	409	FS? 02	465	LBL "X"	521	LBL 23
298	I	354	RCL 00	410	"W"	466	"L"	522	"ESTIM. d+D"
299	ST+ 10	355	-	411	"T/dT : "	467	FS? 02	523	RTN
300	"MORE ? <1/0>"	356	RCL 05	412	XEQ "Z"	468	"W"	524	LBL 24
301	PROMPT	357	/	413	GTO "P"	469	RTN	525	"T<0>/S.+AGE"
302	X#0?	358	RCL 12	414	LBL 09	470	LBL "0"	526	RTN
303	GTO "Q"	359	YIX	415	FS? 01	471	FS? 55	527	LBL 25
304	RCL 13	360	RCL 02	416	RCL 01	472	SF 21	528	"SIZE/INFL.P"
305	RCL 10	361	*	417	FS? 02	473	ADV	529	RTN
306	/	362	LBL 01	418	RCL 02	474	ADV	530	LBL 26
307	STO 04	363	XEQ "X"	419	/	475	XEQ IND X	531	"GROWTH R."
308	FC? 55	364	"T. >INFL< : "	420	FS? 01	476	AVIEW	532	RTN
309	GTO 01	365	GTO "Z"	421	RCL 00	477	PSE	533	LBL 50
310	SF 21	366	LBL G	422	FS? 02	478	CLA	534	STO L
311	ADV	367	26	423	RCL 11	479	ADV	535	FS? 03
312	"MEAN "	368	XEQ "0"	424	YIX	480	CF 21	536	I
313	ACA	369	LBL "P"	425	CHS	481	X<Y	537	FS? 04
314	SF 13	370	FIX 2	426	I	482	ARCL X	538	12
315	"T<0> : "	371	XEQ "X"	427	+	483	AVIEW	539	FS? 05
316	ACA	372	"T <T> ?"	428	LN	484	PSE	540	365
317	CF 13	373	XEQ "Y"	429	RCL 08	485	RTN	541	END.
318	ACX	374	XEQ 09	430	CHS	486	LBL "Z"		
319	PRBUF	375	XEQ 10	431	/	487	FS? 55		
320	ADV	376	STO 13	432	RTN	488	GTO 01		
321	CF 21	377	FS? 01	433	LBL 10	489	ARCL X		
322	LBL 01	378	RCL 09	434	RCL 08	490	PROMPT		
323	"MEAN T<0> : "	379	FS? 02	435	*	491	RTN		
324	ARCL X	380	RCL 12	436	FS?C 09	492	LBL "Y"		
325	PROMPT	381	I	437	XEQ 01	493	PROMPT		
326	GTO "Q"	382	-	438	CHS	494	FC? 55		
327	LBL F	383	YIX	439	EIX	495	RTN		
328	FIX 2	384	RCL 13	440	CHS	496	LBL "V"		
329	25	385	I	441	I	497	LBL 01		
330	XEQ "0"	386	-	442	+	498	SF 21		
331	FS? 02	387	CHS	443	RTN	499	ACA		
332	GTO 02	388	*	444	LBL 01	500	ACX		
333	I	389	FS? 02	445	RAD	501	PRBUF		
334	RCL 00	390	GTO 01	446	RCL 13	502	CF 21		
335	XCY?	391	RCL 01	447	RCL 07	503	RTN		
336	GTO 01	392	*	448	-	504	LBL "W"		

EXAMPLE 3.9

(See also page 50 and 51 in manual)

Data from Appendix I,
Tab. 4.2

* FB 9 *

LENGTH

CONSTANTS :

L>00< : 101.31
K<YR> : 1.966
t<o> :
D : 1.00

T<O>/S.+AGE

L <T> ? 27.00
AGE ? 35.00
t<o> : -0.062
L <T> ? 32.00
AGE ? 51.00
t<o> : -0.053
L <T> ? 42.00
AGE ? 133.00
t<o> : 0.092
L <T> ? 50.00
AGE ? 115.00
t<o> : -0.031
L <T> ? 56.00
AGE ? 147.00
t<o> : -0.007
L <T> ? 70.00
AGE ? 227.00
t<o> : 0.025
L <T> ? 71.00
AGE ? 221.00
t<o> : -0.008
L <T> ? 87.00
AGE ? 375.00
t<o> : 0.032

MEAN t<o> : -0.002

Data from Appendix I,
Tab. 4.2

* FB 9 *

LENGTH

CONSTANTS :

L>00< : 101.31
K<YR> : 1.996
t<o> : -0.002
D : 1.00

SIZE/AGE

AGE ? 50.00
L <T> : 24.54
AGE ? 115.00
L <T> : 47.51
AGE ? 170.00
L <T> : 61.48
AGE ? 220.00
L <T> : 71.01
AGE ? 320.00
L <T> : 83.77
AGE ? 83.77
L <T> : 37.49

AGE/SIZE

L <T> ? 25.00
AGE : 51.09
L <T> ? 50.00
AGE : 123.67
L <T> ? 70.00
AGE : 214.00
L <T> ? 90.00
AGE : 400.20

GROWTH R.

L <T> ? 30.00
dL/dT : 0.39
L <T> ? 50.00
dL/dT : 0.28
L <T> ? 70.00
dL/dT : 0.17
L <T> ? 90.00
dL/dT : 0.06

3.10: PROGRAM DESCRIPTION FB 10

Total Mortality from Mean Weight

Total mortality (Z) can be estimated iteratively from the equation

$$\bar{W} = W_{\infty} \left(1 - \frac{3Z \exp(-a)}{Z + K} + \frac{3Z \exp(-2a)}{Z + 2K} - \frac{Z \exp(-3a)}{Z + 3K} \dots 1 \right)$$

where $a = K(t_c - t_0)$, W_{∞} , K and t_0 being parameters of the special von Bertalanffy Growth Formula, where t_c is the mean age at first capture obtained by a given gear and where $\bar{W}$ is the mean weight of the fishes in the catch (Gulland, 1969). "Knife-edge" selection (at age t_c) is assumed.

The method of iteration used here is the "regula falsi" as incorporated in HP 67/97 program "Solution to $f(x) = 0$ " (HP 67/97 MA108A, Math Pac).

Operating Limits and Warnings

Iteration time depends on the values $f(a)$ and $f(b)$, which should be both close to zero, and on TOL, with low TOL values increasing iteration time.

FB 10: TOTAL MORTALITY FROM MEAN WEIGHT

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM			* FB 10 *
1.	DISPLAY OF MENU:			MENU
1.1	INPUT OF MEAN WEIGHT AND TOL-ERROR			INP. WT./TOL: A
1.2	INPUT OF HIGH AND LOW Z-VALUES			INP. Z H/L : B
1.3	{ SEE GENERAL			MENU : C
1.4	{ INSTRUCTIONS			INIT. : c
				CONSTANTS:
2.	ENTER CONSTANTS:			ENTER:
				W<00> ?
2.1	ASYMPTOTIC WEIGHT	W_{∞}	R/S	K<YR> ?
2.2	K (ON ANNUAL BASIS)	K	R/S	T<C> ?
2.3	MEAN AGE AT FIRST CAPTURE (IN YEARS)	t_c	R/S	T<O> ?
2.4	AGE AT LENGTH ZERO (IN YEARS)	t_o	R/S	:
				:
3.	ENTER:			MEAN WT. ?
3.1	MEAN WEIGHT OF THE FISH IN THE CATCH	W	R/S	TOL. ER. ?
3.2	TOLERATED ERROR (E.G. 0.001)	TOL	R/S	:
4.	TO CALCULATE $f(a)$ AND $f(b)$, ENTER ^{a)}			ENTER Z<HI>
4.1	HIGH Z-VALUE	Z HIGH	R/S	F(a): (x)
4.2	OUTPUT: $f(a)$; TO CONTINUE, PRESS		R/S	ENTER Z<LO>
4.3	ENTER LOW Z-VALUE	Z LOW	R/S	F(b): (x)
				PLEASE WAIT

a) NOTE: IF $f(a) > 0$ OR $f(b) < 0$, PRESSING "R/S" BRINGS YOU BACK TO THE RESPECTIVE STEP FOR A NEW Z-INPUT.

FB 10: TOTAL MORTALITY FROM MEAN WEIGHT

USER INSTRUCTIONS (cont.)

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
5.	RESULT: ESTIMATE OF TOTAL MORTALITY			Z: (x)
6.	OPTIONS:			
6.1	CHANGE INPUT FOR Z<HI> AND/OR Z<LO> (GO TO STEP 4).		B	ENTER Z<HI>
6.2	CHANGE INPUT FOR MEAN WEIGHT AND/OR TOLERATED ERROR (GO TO STEP 3.)		A	MEAN WT. ?
6.3	CHANGE INPUT OF CONSTANTS (GO TO STEP 2.)		f c	CONSTANTS:
6.4	REVIEW MENU:		C	MENU:

REGISTERS, STATUS, FLAGS

PROGR. NAME: FB 10 (Total Mortality from Mean Weight)

STATUS : REG. (PROGR.): 100
SIZE (MIN.) : 015 SIZE (MAX.): -

FLAGS : 10

ASSIGNMENTS:

A: GENERAL COMMANDS

B: SPECIAL COMMANDS

INITIALIZE : (f)c
RECALL MENU : C

INP. MEAN WEIGHT/TOL : A
INP. Z<HI> AND Z<LO> : B

REGISTERS :

SUB-

PROGR.:

00 : [u]
01 : K
02 : [u]
03 : [u]
04 : W< ∞ >
05 : [u]
06 : [u]
07 : [u]
08 : [u]
09 : [u]
10 : [u]
11 : [u]
12 : [u]
13 : [u]
14 : [u]

A B

RESULTS
ARE
STORED
IN
X-REGISTER

Program Listing

(FB 10)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01	LBL "FB 10"	57	SF 21	113	SF 13	169	RCL 13	225	RCL 11
02	SF 10	58	ADV	114	"F"	170	RCL 12	226	STO 10
03	CF 21	59	ADV	115	XEQ "M"	171	-	227	X<> 12
04	" * FB 10 *"	60	CF 21	116	CF 13	172	ABS	228	STO 11
05	XEQ "0"	61	"MEAN WT."	117	X<0?	173	X<=Y?	229	RCL 08
06	SF 27	62	XEQ 03	118	GTO "U"	174	GTO 11	230	STO 07
07	LBL C	63	STO 06	119	"PLEASE WAIT"	175	RCL 02	231	X<> 09
08	"MENU :"	64	"TOL."	120	AVIEW	176	RCL 13	232	STO 08
09	AVIEW	65	XEQ 06	121	LBL "K"	177	RCL 11	233	GTO "K"
10	PSE	66	STO 14	122	RCL 08	178	-	234	LBL 10
11	"INP. WT./TOL: A"	67	GTO B	123	X=0?	179	ABS	235	STO 03
12	AVIEW	68	LBL 06	124	GTO 14	180	X>Y?	236	RCL 05
13	PSE	69	SF 55	125	RCL 11	181	GTO 12	237	2
14	PSE	70	"F "	126	RCL 12	182	X<>Y	238	*
15	"INP. Z H/L : B"	71	LBL 07	127	-	183	RCL 12	239	CHS
16	AVIEW	72	SF 55	128	ABS	184	RCL 11	240	E+X
17	PSE	73	"F "	129	RCL 14	185	-	241	*
18	PSE	74	LBL 03	130	X>Y?	186	ENTER↑	242	3
19	"MENU : C"	75	SF 55	131	GTO 14	187	ABS	243	*
20	AVIEW	76	XEQ 04	132	2	188	/	244	RCL 01
21	PSE	77	"F 2"	133	/	189	*	245	2
22	"INIT.: c"	78	PROMPT	134	1 E-9	190	RCL 11	246	*
23	AVIEW	79	FC? 55	135	RCL 11	191	+	247	RCL 03
24	SF 20 10	80	RTN	136	*	192	STO 13	248	+
25	GTO 01	81	CLA	137	+	193	GTO 12	249	/
26	STOP	82	"F: "	138	STO 02	194	LBL 11	250	RCL 05
27	GTO C	83	GTO "X"	139	RCL 08	195	RCL 11	251	CHS
28	LBL 01	84	LBL 04	140	RCL 07	196	RCL 12	252	E+X
29	PSE	85	SF 21	141	RCL 08	197	+	253	RCL 03
30	LBL c	86	ACA	142	-	198	2	254	*
31	CLRG	87	CF 21	143	RCL 10	199	/	255	3
32	XEQ "S"	88	RTN	144	RCL 11	200	STO 13	256	*
33	PSE	89	LBL B	145	-	201	LBL 12	257	RCL 01
34	"ENTER "	90	FIX 2	146	/	202	RCL 11	258	RCL 03
35	AVIEW	91	SF 21	147	/	203	STO 10	259	+
36	PSE	92	ADV	148	RCL 11	204	RCL 08	260	/
37	"W<00>"	93	CF 21	149	X<>Y	205	STO 07	261	-
38	FIX 3	94	"Z <HI>"	150	-	206	RCL 13	262	RCL 05
39	XEQ 03	95	XEQ "L"	151	STO 13	207	STO 11	263	3
40	STO 04	96	STO 11	152	RCL 11	208	XEQ 10	264	*
41	"K<YR>"	97	XEQ 10	153	-	209	STO 08	265	CHS
42	FIX 3	98	STO 08	154	RCL 12	210	RCL 09	266	E+X
43	XEQ 03	99	SF 13	155	RCL 11	211	*	267	RCL 03
44	STO 01	100	"F<a>"	156	-	212	X<0?	268	*
45	SF 13	101	XEQ "M"	157	/	213	GTO 13	269	RCL 01
46	"T<c>"	102	CF 13	158	X<0?	214	RCL 10	270	3
47	XEQ 07	103	X>0?	159	GTO 11	215	STO 12	271	*
48	STO 05	104	GTO B	160	1	216	RCL 07	272	RCL 03
49	"T<0>"	105	LBL "U"	161	X<=Y?	217	STO 09	273	+
50	XEQ 07	106	"Z <LO>"	162	GTO 11	218	LBL 13	274	/
51	ST- 05	107	XEQ "L"	163	RCL 11	219	RCL 09	275	-
52	RCL 01	108	STO 10	164	RCL 12	220	ABS	276	1
53	ST* 05	109	STO 12	165	-	221	RCL 08	277	+
54	CF 13	110	XEQ 10	166	ABS	222	ABS	278	RCL 04
55	LBL A	111	STO 07	167	4	223	X<=Y?	279	*
56	FIX 3	112	STO 09	168	/	224	GTO "K"	280	RCL 06

Program Listing

(FB 10 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
281	-	337	AVIEW						
282	RTN	338	FC? 55						
283	*LBL 14	339	RTN						
284	BEEP	340	SF 21						
285	SF 21	341	ADV						
286	ADV	342	*LBL 01						
287	RCL 11	343	ACA						
288	*LBL E	344	PRBUF						
289	"Z : "	345	CF 12						
290	FS? 55	346	CF 21						
291	XEQ "X"	347	.END.						
292	SF 21								
293	ADV								
294	CF 21								
295	ARCL X								
296	PROMPT								
297	GTO C								
298	*LBL "L"								
299	FIX 2								
300	ASTO X								
301	"ENTER "								
302	ARCL X								
303	PROMPT								
304	FC? 55								
305	RTN								
306	"FOR "								
307	ARCL Y								
308	"F : "								
309	GTO "X"								
310	*LBL "M"								
311	"F : "								
312	FS? 55								
313	XEQ "Y"								
314	APPL X								
315	PROMPT								
316	RTN								
317	*LBL "Y"								
318	SF 21								
319	ACA								
320	APX								
321	PRBUF								
322	CF 21								
323	RTN								
324	*LBL "0"								
325	AVIEW								
326	PSE								
327	FC? 55								
328	RTN								
329	SF 21								
330	ADV								
331	ADV								
332	SF 12								
333	GTO 01								
334	*LBL "S"								
335	"CONSTANTS :"								
336	BEEP								

EXAMPLE 3.10

(See also page 78 in manual)

* FB 10 *

CONSTANTS :
W(00): 10.000
K(YR): 0.500
t(c): 0.950
t(o): -0.000

MEAN WT.: 5.000
TOL. : 0.001

FOR Z <HI> : 4.00
f(a) : -2.47
FOR Z <LO> : 0.10
f(b) : 3.34

Z : 0.58

3.11: PROGRAM DESCRIPTION FB 11

Z Using Jones' or Sparre's Method

Jones (1981) showed that Z/K is equal to the slope of the straight part of a plot $\ln C$ on $\ln (L_{\infty} - L_1)$, where C is the cumulative catch (starting from the highest length class) corresponding to a given length class of which L_1 is the lower class limit.

The method has been modified by P. Sparre (pers. comm. to Pauly 1984) who showed that K can be estimated from the slope of the straight part of a plot of $\ln C$ on the age corresponding to L_1 , where both $\ln C$ and L_1 are defined as above. When K is not known, using 1 (one) instead of K for the transformation of length to age makes the slope of the plot equal to Z/K .

Both methods were here modified for use with the generalized VBGF, by addition of the parameter D where appropriate. Also, the ages (t) in Sparre's method are here replaced by relative ages ($t' = t - t_0$).

Operating Limits and Warnings

- 1) Proper selection of the abscissa and ordinate values to be included in the computation of Z or Z/K requires that a graph be made from which the points belonging to the straight section are selected.
- 2) Do not use the method with data obtained from a gear that selects for or against large sizes.

FB 11: Z USING JONES' OR SPARRE'S METHOD

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM			* FB 11 * NEW INPUT ? YES: 1, NO: 0
1.	INDICATE WHETHER YOU WANT TO ENTER A NEW DATA SET ("1") OR USE DATA PREVIOUSLY STORED VIA FB 12 ("0")			
2.	<u>NEW DATA INPUT:</u> ENTER:	1	R/S	ENTER CONST. L <00> ?
2.1	ASYMPTOTIC LENGTH	L_{∞}	R/S	D ?
2.2	$D^a)$	D^{∞}	R/S	K ?
2.3	$K^b)$	K	R/S	L<MIN> ?
2.4	LOWER CLASS LIMIT OF:			
2.4.1	LOWEST LENGTH CLASS WITH NON-ZERO CATCH	L_{min}	R/S	L<MAX> ?
2.4.2	HIGHEST LENGTH CLASS WITH NON-ZERO CATCH	L_{max}	R/S	dL ?
2.5	CLASS WIDTH	ΔL	R/S	DATA INPUT: : (MENU)
2.6	FOR LENGTH CLASS $L_{min} \dots L_{max}$ ENTER CATCH	C	R/S	C<(L)> ? C<(L+1)> ? : (MENU)
3.	<u>USE OF PREVIOUSLY STORED DATA (FB 12)</u>	0	R/S	(MENU)
4.	DISPLAY OF MENU:			MENU
4.1	Z-ESTIMATE, "JONES' METHOD"			Z.>JON.<: A
4.2	Z-ESTIMATE, "SPARRE'S METHOD"			Z.>SPAR.<: B
4.3	CORRECTION OF DATA INPUT			DATA CORR.: D
4.4	COMPUTATION OF RESULTS			RES<J/SP>: E

NOTE:

a) IF NO VALUE FOR D IS AVAILABLE, PRESS "R/S" AND CONTINUE WITH NEXT STEP (D IS SET EQUAL TO 1, AS IN CASE OF THE SPECIAL VBGF).

b) IF NO VALUE FOR K IS AVAILABLE, PRESS "R/S" AND CONTINUE WITH NEXT STEP (K IS SET EQUAL TO 1; RESULTS OBTAINED ARE ESTIMATES OF Z/K).

FB 11: Z USING JONES' OR SPARRE'S METHOD

USER INSTRUCTIONS (cont.)

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
4.5	CHANGE SELECTION OF CURVE RANGE (I.E. POINTS INCLUDED)			SEL. RANGE: e
4.6	{ SEE GENERAL			INITIAL.: c
4.7	{ INSTRUCTIONS			MENU: C
5.	<u>CUMULATIVE PLOT</u> SELECT CASE: ^{a)}			
5.1	CASE I: JONES' METHOD		A	(OUTPUT)
5.2	CASE II: SPARRE'S METHOD		B	(OUTPUT)
6.	OUTPUT FOR CUMULATIVE PLOT:			
6.1	<u>CASE I</u> FOR CATCH PERTAINING TO $L_{\max} \dots L_{\min}^D$ X-AXIS : $\ln(L - L_i^D)$ Y-AXIS : $\ln C(L_i^{\infty})$		R/S	C<(L)>: (x) (PROGR. STOP) LN<X>: (x) LN>C<: (x) C<(L-1)>: (x) (PROGR. STOP)
6.2	<u>CASE II</u> FOR CATCH PERTAINING TO $L_{\max} \dots L_{\min}$ X-AXIS : RELATIVE AGE Y-AXIS : $\ln C(L_i^{\infty})$		R/S	C<(L)>: (x) (PROGR. STOP) R. AGE: (x) LN>C<: (x) (PROGR. STOP) C<(L-1)>: (x)
7.	OPTIONS:			
7.1	REVIEW OUTPUT OF CASE I		A	Z-ESTIM.: R/S
7.2	REVIEW OUTPUT OF CASE II		B	
7.3	CORRECT DATA INPUT (CATCH DATA) ^{b)}		D	
7.4	PROCEED TO COMPUTE Z (OR Z/K)		R/S	

NOTE:

a) TO FACILITATE IDENTIFICATION OF THE METHOD UNDER CONSIDERATION, FLAG INDICATORS ARE DISPLAYED (1: JONES' METHOD, 2: SPARRE'S METHOD).

b) SEE FB 12 FOR PROCEDURE.

FB 11: Z USING JONES' OR SPARRE'S METHOD

USER INSTRUCTIONS (cont.)

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
8.	COMPUTATION OF Z (OR Z/K) USE THE OUTPUT FROM CUMULATIVE PLOT TO DETERMINE THE RANGE OF THE CURVE TO BE INCLUDED IN COMPUTATION OF Z (OR Z/K)		R/S	FOR CURVE: SELECT RANGE: P<1> ?
8.1	ENTER "P1" (LOWER CLASS LIMIT OF LOWEST LENGTH CLASS CONSIDERED)	P1	R/S	P<2> ?
8.2	ENTER "P2" (LOWER CLASS LIMIT OF HIGHEST LENGTH CLASS CONSIDERED)	P2	R/S	PLEASE WAIT :
9.	DISPLAY OF RESULTS ^{a)}			RESULTS
9.1	COEFFICIENT OF DETERMINATION (r^2)			R^2 : (x)
9.2	a			a : (x)
9.3	b			b : (x)
9.4	Z (OR Z/K, IF NO VALUE OF K ENTERED)			Z : (x)
10.	OPTIONS:			
10.1	COMPUTE RESULTS USING THE ALTERNATIVE METHOD (WITH IDENTICAL PARAMETER VALUES) ^{b)}		E	PLEASE WAIT
10.2	RECOMPUTE RESULTS OF PRESENT METHOD USING A DIFFERENT RANGE OF THE CURVE		f e	FOR CURVE:
10.3	REVIEW OUTPUT OF CASE I OR II		A OR B	
10.4	REVIEW MENU		C	(MENU)
10.5	APPLY PRESENTLY STORED DATA SET TO "FB 12" (TO CONT., SEE USER INSTR. FOR FB 12) LOAD PROGRAM "FB 12"			* FB 12 *
10.6	FOR A NEW SET OF DATA, INITIALIZE		f c	ENTER CONST.

NOTE:

a) SEE FB 12 FOR PROCEDURE

b) FLAG NO. (1: JONES' METHOD, 2: SPARRE'S METHOD) INDICATE METHOD USED.

REGISTERS, STATUS, FLAGS

PROGR. NAME: FB 11 (Z Using Jones' or Sparre's Method)

STATUS : REG. (PROGR.): 150
 SIZE (MIN.) : (k)+21 SIZE (MAX.): 169

FLAGS : 1, 2, 7 - 9

ASSIGNMENTS:

A: GENERAL COMMANDS

B: SPECIAL COMMANDS

INITIALIZE : (f)c
 RECALL MENU : C

JONES' METHOD : A
 SPARRE'S METHOD : B
 DATA CORRECTION : D
 RANGE SELECTION : (f)e
 COMP. ALTERNATE RES. : E

REGISTERS :

SUB- PROGR.:	A	B	A	B
			└──────────┘	
00 :	D	D		
01 :	L<∞>	L<∞>	RESULTS	
02 :	K	K	ARE	
03 :	[u]	[u]	STORED	
04 :	[u]	[u]	IN	
05 :	[u]	[u]	X-REGISTER	
06 :	[u]	[u]		
07 :	[u]	[u]		
08 :	[u]	[u]		
09 :	[u]	[u]		
10 :	[u]	[u]		
11 :	[u]	[u]		
12 :	b	b		
13 :	a ₂	a ₂		
14 :	r ₂	r ₂		
15 :	[u]	[u]		
16 :	[u]	[u]		
17 :	[u]	[u]		
18 :	[u]	[u]		
19 :	[u]	[u]		
20 :	[u]	[u]		
21 :	C(1)	C(1)		
22 :	C(2)	C(2)		
	.	.		
	.	.		
	C(k)	C(k)		

 NOTE: "k" REPRESENTS NUMBER OF CASES (= NO. OF ROWS)

Program Listing

(FB 11)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01*LBL "FB 11"		57 -		113*LBL 02		169 XEQ 10		225 FS? 07	
02 " * FB 11 *		58 RCL 04		114 SF 21		170 FS? 02		226 RTN	
03 FC? 55		59 /		115 ADV		171 GTO 01		227 "F: "	
04 GTO 01		60 CHS		116 "CONSTANTS :"		172 "LN <X>"		228 RCL IND 07	
05 SF 21		61 21		117*LBL 00		173 GTO 02		229 FIX 2	
06 ADV		62 STO 11		118 SF 21		174*LBL 01		230 FS? 55	
07 ADV		63 +		119 AOA		175 "R. AGE"		231 XEQ 08	
08 SF 12		64 3		120 PRBUF		176*LBL 02		232 ARCL X	
09 XEQ 00		65 101X		121 CF 21		177 FIX 3		233 AVIEW	
10*LBL 01		66 /		122 CF 12		178 XEQ "P"		234 FC? 55	
11 AVIEW		67 ST+ 11		123 RTN		179 RCL 10		235 STOP	
12 SF 27		68*LBL D		124*LBL 06		180 LN		236 RTN	
13 SREG 15		69 "DATA INPUT :"		125 FS? 55		181 "LN >C<"		237*LBL 07	
14 PSE		70 AVIEW		126 "F: "		182 XEQ "P"		238 RCL 03	
15 BEEP		71 SF 02		127*LBL 03		183 RCL 04		239 STO 06	
16 "NEW INPUT ?"		72 PSE		128 FS? 55		184 ST+ 06		240 0	
17 AVIEW		73 RCL 11		129 XEQ 04		185 DSE 07		241 STO 10	
18 PSE		74 STO 12		130 "F ?"		186 GTO 12		242 0	
19 "YES: 1, NO: 0"		75 RCL 05		131 PROMPT		187 "Z-ESTIM"		243 3	
20 PROMPT		76 STO 06		132 FC? 22		188 FS? 05		244 101X	
21 X=0?		77 SF 07		133 1		189 "Z/K-EST"		245 /	
22 GTO C		78*LBL 20		134 FC? 55		190 "F: R/S"		246 STO 07	
23*LBL C		79 XEQ 11		135 RTN		191 PROMPT		247 RCL 11	
24 CF 01		80 "F?"		136 " : "		192 GTO E		248 FRC	
25 CF 02		81 PROMPT		137 GTO "X"		193*LBL 10		249 3	
26 CLRG		82 STO IND 12		138*LBL 04		194*LBL "K"		250 101X	
27 "ENTER CONST.:"		83 RCL 04		139 SF 21		195 ST+ 10		251 *	
28 AVIEW		84 ST- 06		140 AOA		196 FS? 09		252 ST+ 07	
29 FS? 55		85 ISG 12		141 CF 21		197 RTN		253 RTN	
30 XEQ 02		86 GTO 20		142 RTN		198 RCL 01		254*LBL 08	
31 PSE		87*LBL C		143*LBL B		199 RCL 00		255*LBL "X"	
32 "L<00> "		88 BEEP		144 CF 01		200 Y1X		256 SF 21	
33 FIX 3		89 "MENU :"		145 SF 02		201 RCL 06		257 AOA	
34 XEQ 03		90 AVIEW		146 XEQ "U"		202 RCL 00		258 ACX	
35 STO 01		91 PSE		147 GTO 01		203 Y1X		259 PRBUF	
36 CF 22		92 "Z >JON.< : A"		148*LBL A		204 -		260 CF 21	
37 "D "		93 AVIEW		149 CF 02		205 FS? 01		261 RTN	
38 XEQ 03		94 PSE		150 SF 01		206 GTO 01		262*LBL 09	
39 STO 00		95 "Z >SPAR.< : B"		151 XEQ "W"		207 RCL 01		263*LBL "P"	
40 CF 22		96 AVIEW		152*LBL 01		208 RCL 00		264 "F: "	
41 "K "		97 PSE		153 CF 07		209 Y1X		265 FS? 55	
42 XEQ 03		98 "DATA CORR.: D"		154 CF 08		210 /		266 XEQ "X"	
43 FC? 22		99 AVIEW		155 SF 21		211*LBL 01		267 ARCL X	
44 SF 05		100 PSE		156 ADV		212 LN		268 FS? 55	
45 STO 02		101 "RES. <J/SP>: E"		157 ADV		213 FS? 01		269 RTN	
46 "L <MIN>"		102 AVIEW		158 CF 21		214 RTN		270 TONE 7	
47 XEQ 03		103 PSE		159 "CUMUL. PLOT :"		215 CHS		271 AVIEW	
48 STO 05		104 "SEL. RANGE : e"		160 FS? 55		216 RCL 02		272 PSE	
49 "L <MAX>"		105 AVIEW		161 XEQ "X"		217 RCL 00		273 PSE	
50 XEQ 03		106 PSE		162 XEQ 07		218 *		274 PSE	
51 STO 03		107 "INITIAL.: c"		163*LBL 12		219 /		275 RTN	
52 "dL"		108 AVIEW		164 FIX 1		220 RTN		276*LBL J	
53 XEQ 03		109 PSE		165 SF 21		221*LBL 11		277 CF 08	
54 ST- 04		110 "MENU : C"		166 ADV		222 "C <"		278*LBL e	
55 RCL 03		111 PROMPT		167 CF 21		223 ARCL 06		279 CF 08	
56 RCL 05		112 GTO C		168 XEQ 11		224 "F: "		280*LBL E	

Program Listing

(FB 11 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
281	CLZ	337	DSE 07	393	"a "				
282	CF 09	338	GTO "L"	394	XEQ "P"				
283	FC? 00	339	LBL 02	395	RCL 12				
284	GTO 02	340	RCL 19	396	"b "				
285	FS? 02	341	RCL 15	397	XEQ "P"				
286	GTO 01	342	RCL 17	398	CF 13				
287	SF 02	343	*	399	ABS				
288	CF 01	344	RCL 20	400	RCL 00				
289	GTO 16	345	/	401	*				
290	LBL 01	346	-	402	FS? 02				
291	CF 02	347	STO 12	403	GTO 01				
292	SF 01	348	X+2	404	RCL 02				
293	GTO 16	349	RCL 18	405	*				
294	LBL 02	350	RCL 17	406	LBL 01				
295	SF 21	351	X+2	407	"Z"				
296	ADV	352	RCL 20	408	FS? 05				
297	CF 21	353	/	409	"F/K"				
298	FIX 2	354	-	410	FC? 05				
299	"FOR CURVE :"	355	/	411	"f "				
300	AVIEW	356	RCL 16	412	XEQ "P"				
301	PSE	357	RCL 15	413	SF 08				
302	FS? 55	358	X+2	414	CLX				
303	XEQ 00	359	RCL 20	415	FS? 55				
304	"SELECT RANGE:"	360	/	416	CLD				
305	AVIEW	361	-	417	STOP				
306	PSE	362	ST/ 12	418	GTO C				
307	"P(1)"	363	/	419	LBL "W"				
308	XEQ 03	364	STO 14	420	"JONES"				
309	STO 08	365	RCL 17	421	ASTO X				
310	"P(2)"	366	RCL 12	422	RTN				
311	XEQ 03	367	RCL 15	423	LBL "U"				
312	STO 09	368	*	424	"SPARRE"				
313	LBL 16	369	-	425	ASTO X				
314	"PLEASE WAIT"	370	RCL 20	426	.END.				
315	AVIEW	371	/						
316	XEQ 07	372	STO 13						
317	LBL "L"	373	SF 21						
318	RCL 06	374	ADV						
319	RCL 09	375	CF 21						
320	X<Y?	376	"U"						
321	SF 09	377	FS? 01						
322	X<Y	378	"W"						
323	RCL 08	379	ASTO X						
324	X>Y?	380	XEQ IND X						
325	GTO 02	381	"Z"						
326	RCL IND 07	382	FS? 05						
327	XEQ "K"	383	"F/K"						
328	FS?C 09	384	"f-ESTIMATE"						
329	GTO 01	385	FS? 55						
330	RCL 10	386	XEQ "X"						
331	LN	387	FIX 3						
332	X<Y	388	SF 13						
333	S+	389	RCL 14						
334	LBL 01	390	"R12"						
335	RCL 04	391	XEQ "P"						
336	ST+ 06	392	RCL 13						

EXAMPLE 3.11

(See also page 80-81 in manual)

Data from Appendix I,
Tab. 5.4

* FB 11 *

.CONSTANTS :

L<00> : 30.900

D : 1.000

K : 0.510

L <MIN> : 4.000

L <MAX> : 26.000

dL : 2.000

C <10.0> : 161.00

LN <X> : 3.040

LN >C< : 6.300

CUMUL. PLOT : "JONES"

C <8.0> : 114.00

LN <X> : 3.131

LN >C< : 6.557

C <26.0> : 4.00

LN <X> : 1.589

LN >C< : 1.386

C <6.0> : 29.00

LN <X> : 3.215

LN >C< : 6.597

C <24.0> : 4.00

LN <X> : 1.932

LN >C< : 2.079

C <4.0> : 5.00

LN <X> : 3.292

LN >C< : 6.604

C <22.0> : 17.00

LN <X> : 2.106

LN >C< : 3.219

FOR CURVE :

P<1> : 10.00

P<2> : 24.00

C <20.0> : 32.00

LN <X> : 2.389

LN >C< : 4.043

Z-ESTIMATE "JONES"

r¹² : 0.998

a : -5.235

b : 3.846

Z : 1.961

C <18.0> : 50.00

LN <X> : 2.557

LN >C< : 4.673

C <16.0> : 61.00

LN <X> : 2.701

LN >C< : 5.124

C <14.0> : 118.00

LN <X> : 2.827

LN >C< : 5.656

C <12.0> : 143.00

LN <X> : 2.939

LN >C< : 6.061

EXAMPLE 3.11 (Cont.)

CONSTANTS :

L<00> : 30.900

D : 1.000

K : 0.510

L <MIN> : 4.000

L <MAX> : 26.000

dL : 2.000

C <10.0> : 161.00

R. AGE : 0.767

LN >C< : 6.380

CUMUL. PLOT : "SPARRE"

C <8.0> : 114.00

R. AGE : 0.587

LN >C< : 6.557

C <26.0> : 4.00

R. AGE : 3.611

LN >C< : 1.386

C <6.0> : 29.00

R. AGE : 0.423

LN >C< : 6.597

C <24.0> : 4.00

R. AGE : 2.940

LN >C< : 2.079

C <4.0> : 5.00

R. AGE : 0.272

LN >C< : 6.604

C <22.0> : 17.00

R. AGE : 2.441

LN >C< : 3.219

FOR CURVE :

P<1> : 10.00

P<2> : 24.00

C <20.0> : 32.00

R. AGE : 2.043

LN >C< : 4.043

Z-ESTIMATE "SPARRE"

r[†]2 : 0.998

a : 7.959

b : -1.961

Z : 1.961

C <18.0> : 50.00

R. AGE : 1.713

LN >C< : 4.673

C <16.0> : 61.00

R. AGE : 1.430

LN >C< : 5.124

C <14.0> : 118.00

R. AGE : 1.183

LN >C< : 5.656

C <12.0> : 143.00

R. AGE : 0.964

LN >C< : 6.061

3.12: PROGRAM DESCRIPTION FB 12

Length-Converted Catch Curves

Given inputs of L_{∞} , K , D and ΔL (the class interval) and length-frequency data, this program computes values of $\ln N/\Delta t$ and t' (relative age) as used for drawing length-converted catch curves (Pauly 1980a). Once the points of the curve have been graphed, the range of data pairs can be selected which are to be included in the estimation of Z , using linear regression (equation 1). Z is estimated from

$$\ln (N/\Delta t) = a - Zt' \quad \dots 1)$$

the value of Z obtained from (1) can then be used as input (Z_1) in the equation of P. Sparre (see manual, p. 64), i.e.

$$\ln (N/(1-e^{-(Z_1\Delta t)})) = a - Z_2t' \quad \dots 2)$$

where Z_2 is an improved estimate of Z . If the value of Z_1 and Z_2 differ markedly, Z_2 is used as input for another iteration, which will then produce a value of Z improved further (Z_3), etc. These iterations are performed semi-automatically by FB 12, and should be stopped when no further improvement occurs.

Operating Limits and Warnings

Selection of range of points to be included in the regression must be done carefully; particularly, no points belonging to the ascending part of the curve must be included, nor points estimated from lengths within about 5% of L_{∞} .

FB 12: LENGTH-CONVERTED CATCH CURVES

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM			* FB 12 *
1.	INDICATE WHETHER YOU WANT TO ENTER A NEW DATA SET ("1") OR USE DATA STORED PREVIOUSLY VIA FB 11 ("0")			NEW INPUT ? YES: 1, NO: 0
2.	<u>NEW DATA INPUT:</u> ENTER:	1	R/S	ENTER CONST.: L<00> ?
2.1	ASYMPTOTIC LENGTH	L_{∞}	R/S	D ?
2.2	D ^{a)}	D	R/S	K ?
2.3	K ^{b)}	K	R/S	L<MIN> ?
2.4	LOWER CLASS LIMIT OF:			
2.4.1	LOWEST LENGTH CLASS WITH NON-ZERO CATCH	L_{min}	R/S	L<MAX> ?
2.4.2	HIGHEST LENGTH CLASS WITH NON-ZERO CATCH	L_{max}	R/S	dL ?
2.5	CLASS WIDTH	ΔL	R/S	DATA INPUT:
2.6	FOR LENGTH CLASS $L_{min} \dots L_{max}$ ENTER CATCH ^{c)}	C	R/S	C<(L)> ? C<(L+1)> ? (MENU)
3.	<u>USE OF PREV. STORED DATA</u> <u>(FB 11)</u>	0	R/S	(MENU)
4.	DISPLAY OF MENU:			MENU:
4.1	CATCH CURVE			CATCH C.: A
4.2	CORRECTION OF DATA INPUT			DATA CORR.: D

NOTES:

a) IF NO VALUE OF D AVAILABLE, PRESS "R/S" AND CONTINUE AT NEXT STEP (D IS SET EQUAL TO 1, AS IN CASE OF THE SPECIAL VBGF).

b) IF NO VALUE OF K AVAILABLE, PRESS "R/S" AND CONTINUE AT NEXT STEP (K IS SET EQUAL TO 1; RESULTS OBTAINED ARE Z/K-ESTIMATES)

c) IF AN ERRONEOUS CATCH INPUT IS DISCOVERED, PRESS "D" AND RE-ENTER CATCHES, STARTING WITH THE LOWEST LENGTH CLASS AND ENDING WITH THE LENGTH CLASS CONTAINING THE ERRONEOUS INPUT.

FB 12: LENGTH-CONVERTED CATCH CURVES

USER INSTRUCTIONS (cont.)

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
4.3	PRELIMINARY ESTIMATE OF Z			Z(PREL.): E
4.4	CHANGE SELECTION OF CURVE RANGE			SEL. RANGE: e
4.5	<u>SEE GENERAL INSTRUCTIONS</u>			INITIAL.: c
4.6				MENU: C
5.	<u>FOR COMPUTATION OF X/Y-DATA</u> PAIRS: TO OBTAIN POINTS FOR CATCH CURVE, PRESS OUTPUT: WITH $L=L_{\min} \dots L_{\max}$		A	(OUTPUT) C<(L)>: (x)
5.1	CATCH INPUT BY LENGTH CLASS (MIDPOINT)			LN<Y>: (x)
5.2	Y-AXIS: LN FREQUENCIES		R/S	R. AGE: (x)
5.3	X-AXIS: REL. AGES (IN YEARS)			: Z-ESTIM.: R/S
6.	OPTIONS:			
6.1	OBTAIN ANEW DATA FOR CATCH CURVE		A	(OUTPUT)
6.2	COMPUTE ESTIMATE OF TOTAL MORTALITY (Z)		R/S	
7.	<u>COMPUTATION OF Z OR Z/K:</u> USE THE OUTPUT FROM CATCH CURVE TO DETERMINE THE RANGE OF THE CURVE TO BE INCLUDED IN COMPUTATION OF Z (OR Z/K, IF NO K-VALUE IS AVAILABLE)			FOR CURVE SELECT RANGE: P<1> ?
7.1	ENTER			
7.1.1	"P1" (MIDPOINT IS LOWEST LENGTH CLASS CONSIDERED)	P1	R/S	P<2> ?
	"P2" (MIDPOINT OF HIGHEST LENGTH CLASS CONSIDERED)	P2	R/S	OUTLIER ? YES: 1, NO: 0
7.2	OPTION:			
7.2.1	TO EXCLUDE <u>ONE</u> OUTLIER WITHIN THE <u>SELECTED</u> RANGE OF THE CATCH CURVE			

FB 12: LENGTH-CONVERTED CATCH CURVES

USER INSTRUCTIONS (cont.)

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
7.2.1.1	ENTER	1	R/S	L. <EX> ?
7.2.1.2	AND THEN THE MIDPOINT OF THE LENGTH CLASS TO BE EXCLUDED	L	R/S	PLEASE WAIT
7.2.2	NO EXCLUSION: ENTER	0 ^{ex}	R/S	(RESULTS)
8.	DISPLAY OF RESULTS:			Z<1>. ESTIM.:
8.1	COEFFICIENT OF DETERMINATION (r^2)			R^2: (x)
8.2	a			a : (x)
8.3	b			b : (x)
8.4	TOTAL MORTALITY Z (OR Z/K)			Z OR (Z/K): (x) IT.Z<2>: R/S
9.	TO IMPROVE ITERATIVELY PRECEDING ESTIMATE OF Z (OR Z/K), PRESS		R/S	Z<2>-ESTIM.
10.	REPEAT STEP 9. UNTIL CONVERGENCE IS ACHIEVED (I.E. $Z_{i+1} = Z_i$)		R/S	
11.	FOR A NEW SET OF DATA, INITIALIZE		f c	ENTER CONST.:
12.	TO CHANGE ONLY THE VALUES OF P1 AND P2, PRESS		f e	FOR CURVE:
13.	TO USE DATA SET WITH FB 11, LOAD FB 11 (FOR CONT., SEE USER INSTRUCTIONS, FB 11.)			

REGISTERS, STATUS, FLAGS

```

-----
PROGR. NAME:          FB 12 (Length-Converted Catch Curves)
-----
STATUS      :          REG. (PROGR.): 152
                  SIZE (MIN.)      : (k)+21          SIZE (MAX.): 167
-----
FLAGS       :          7 - 10
-----
ASSIGNMENTS:

```

A: GENERAL COMMANDS

B: SPECIAL COMMANDS

INITIALIZE : (f)c
RECALL MENU : C

CATCH CURVE : A
DATA CORRECTION : D
RANGE SELECTION : (f)e

REGISTERS :

SUB-
PROGR.:

```

                                A
                                {
00 :      D
01 :      L<∞>          RESULTS
02 :      K              ARE
03 :      [u]           STORED
04 :      [u]           IN
05 :      [u]           X-REGISTER
06 :      [u]
07 :      [u]
08 :      [u]
09 :      [u]
10 :      [u]
11 :      [u]
12 :      [u]
13 :      Z 2r Z/K
14 :      r
15 :      [u]
16 :      [u]
17 :      [u]
18 :      [u]
19 :      [u]
20 :      [u]
21 :      C(1)
22 :      C(2)
      .
      .
      C(k)

```

NOTE: "k" REPRESENTS NUMBER OF CASES (= NO. OF ROWS)

Program Listing

(FB 12)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01	LBL "FB 12"	57	-	113	ADV	169	RCL IND 07	225	FC? 55
02	" * FB 12 *"	58	RCL 04	114	"CONSTANTS :"	170	X<>Y	226	STOP
03	FC? 55	59	/	115	LBL 00	171	/	227	RTN
04	GTO 01	60	CHS	116	SF 21	172	LN	228	LBL 07
05	SF 21	61	21	117	ACA	173	"LN <Y>"	229	RCL 11
06	ADV	62	STO 11	118	PRBUF	174	FIX 3	230	STO 07
07	ADV	63	+	119	CF 21	175	XEQ 09	231	RCL 05
08	SF 12	64	3	120	CF 12	176	RCL 06	232	XEQ 25
09	XEQ 00	65	10+X	121	RTN	177	XEQ 14	233	-
10	LBL 01	66	/	122	LBL 06	178	"R. AGE"	234	STO 06
11	AVIEW	67	ST+ 11	123	FS? 55	179	XEQ 09	235	RTN
12	SF 27	68	LBL D	124	" + "	180	RCL 04	236	LBL 08
13	SREG 15	69	FIX 2	125	LBL 03	181	ST- 06	237	SF 21
14	0	70	"DATA INPUT "	126	FS? 55	182	ISG 07	238	ACA
15	STO 10	71	AVIEW	127	XEQ 04	183	GTO 12	239	ACX
16	PSE	72	PSE	128	" + ?"	184	"Z-ESTIM.: R/S"	240	PRBUF
17	TONE 7	73	RCL 11	129	PROMPT	185	PROMPT	241	CF 21
18	"NEW INPUT ?"	74	STO 12	130	FC? 22	186	GTO e	242	RTN
19	XEQ 19	75	RCL 05	131	1	187	LBL 10	243	LBL 09
20	X=0?	76	STO 06	132	FS? 55	188	XEQ 10	244	" + : "
21	GTO C	77	SF 07	133	XEQ 05	189	-	245	FS? 55
22	LBL c	78	LBL 20	134	RTN	190	XEQ 14	246	XEQ 08
23	CF 01	79	XEQ 11	135	LBL 04	191	XEQ 18	247	ARCL X
24	CF 02	80	" + ?"	136	SF 21	192	+	248	FS? 55
25	CLRG	81	PROMPT	137	ACA	193	XEQ 14	249	RTN
26	"ENTER CONST.:"	82	STO IND 12	138	CF 21	194	-	250	TONE 7
27	AVIEW	83	RCL 04	139	RTN	195	RTN	251	AVIEW
28	FS? 55	84	ST- 06	140	LBL 05	196	LBL 14	252	PSE
29	XEQ 02	85	ISG 12	141	SF 21	197	RCL 01	253	PSE
30	PSE	86	GTO 20	142	CLA	198	/	254	RTN
31	"L<00>"	87	LBL C	143	" + "	199	RCL 00	255	LBL e
32	FIX 2	88	BEEP	144	ACA	200	1/X	256	CF 08
33	XEQ 03	89	"MENU :"	145	ACX	201	Y+X	257	LBL E
34	CF 22	90	AVIEW	146	PRBUF	202	CHS	258	1
35	"D "	91	PSE	147	CF 21	203	1	259	STO 12
36	XEQ 06	92	"CATCH C.: A"	148	RTN	204	+	260	CF 10
37	STO 00	93	AVIEW	149	LBL A	205	LN	261	FS? 08
38	Y+X	94	PSE	150	CF 07	206	CHS	262	GTO 16
39	STO 01	95	"DATA CORR.: D"	151	SF 21	207	RCL 02	263	SF 21
40	CF 23	96	AVIEW	152	ADV	208	RCL 00	264	ADV
41	"K "	97	PSE	153	ADV	209	*	265	CF 21
42	FIX 3	98	"Z <PREL.> : E"	154	CF 21	210	/	266	FIX 2
43	XEQ 06	99	AVIEW	155	"CATCH CURVE :"	211	RTN	267	"FOR CURVE :"
44	STO 02	100	PSE	156	FS? 55	212	LBL 11	268	AVIEW
45	FIX 2	101	"SEL. RANGE : e"	157	XEQ 00	213	"L <"	269	FS? 55
46	"L<MIN>"	102	AVIEW	158	XEQ 07	214	ARCL 06	270	XEQ 00
47	XEQ 03	103	PSE	159	0	215	" + "	271	PSE
48	STO 05	104	PSE	160	STO 14	216	FS? 07	272	PSE
49	"L<MAX>"	105	"INITIAL.: c"	161	CF 08	217	RTN	273	"SELECT RANGE:"
50	XEQ 03	106	AVIEW	162	LBL 12	218	" + : "	274	AVIEW
51	STO 03	107	PSE	163	FIX 2	219	RCL IND 07	275	PSE
52	"dL"	108	"MENU : C"	164	SF 21	220	FIX 2	276	"L <P1>"
53	XEQ 06	109	AVIEW	165	ADV	221	FS? 55	277	XEQ 01
54	ST- 04	110	RTN	166	CF 21	222	XEQ 08	278	STO 08
55	RCL 03	111	LBL 02	167	XEQ 11	223	ARCL X	279	"L <P2>"
56	RCL 05	112	SF 21	168	XEQ 10	224	AVIEW	280	XEQ 01

Program Listing

(FB 12 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
281	STO 09	337	GTO 22	393	LBL 02	449	AVIEW		
282	GTO 02	338	RCL 04	394	FIX 3	450	PSE		
283	LBL 01	339	2	395	SF 13	451	"YES: 1, NO: 0"		
284	ASTO X	340	/	396	RCL 14	452	PROMPT		
285	"F ?"	341	+	397	"R+2"	453	.END.		
286	PROMPT	342	LBL 22	398	XEQ 09				
287	CLA	343	XEQ 14	399	RCL 17				
288	ARCL Y	344	2+	400	RCL 13				
289	"F:"	345	LBL 01	401	RCL 15				
290	FS? 55	346	RCL 04	402	*				
291	XEQ 08	347	ST- 06	403	-				
292	RTN	348	ISG 07	404	RCL 20				
293	LBL 02	349	GTO 13	405	/				
294	"OUTLIER ?"	350	LBL 02	406	"a "				
295	TONE 7	351	RCL 19	407	XEQ 09				
296	XEQ 19	352	RCL 15	408	RCL 13				
297	X=0?	353	RCL 17	409	"b "				
298	GTO 16	354	*	410	XEQ 09				
299	"L. <EX> ?"	355	RCL 20	411	CF 13				
300	PROMPT	356	/	412	RCL 13				
301	STO 10	357	-	413	ABS				
302	LBL 16	358	STO 13	414	RCL 00				
303	"PLEASE WAIT"	359	X+2	415	*				
304	AVIEW	360	RCL 18	416	RCL 02				
305	CLS	361	RCL 17	417	1				
306	XEQ 07	362	X+2	418	X=Y?				
307	LBL 13	363	RCL 20	419	GTO 01				
308	RCL 10	364	/	420	RCL Z				
309	RCL 06	365	-	421	GTO 02				
310	X=Y?	366	/	422	LBL 01				
311	GTO 01	367	RCL 16	423	RCL Z				
312	RCL 08	368	RCL 15	424	"Z/K"				
313	X>Y?	369	X+2	425	GTO 01				
314	GTO 01	370	RCL 20	426	LBL 02				
315	X<Y	371	/	427	"Z "				
316	RCL 09	372	-	428	LBL 01				
317	X<Y?	373	ST/ 13	429	STO 13				
318	GTO 02	374	/	430	XEQ 09				
319	RCL IND 07	375	STO 14	431	SF 08				
320	XEQ 10	376	SF 21	432	1				
321	FC? 10	377	ADV.	433	ST+ 12				
322	GTO 21	378	CF 21	434	FIX 0				
323	RCL 13	379	FIX 0	435	"IT. Z<"				
324	*	380	TONE 7	436	ARCL 12				
325	CHS	381	"Z <"	437	"F> : R/S"				
326	E+X	382	ARCL 12	438	PROMPT				
327	CHS	383	"F> ESTIM"	439	SF 10				
328	1	384	FS? 55	440	GTO 16				
329	+	385	GTO 01	441	LBL 18				
330	LBL 21	386	"F.:"	442	RCL 06				
331	RCL IND 07	387	AVIEW	443	LBL 25				
332	X<Y	388	PSE	444	RCL 04				
333	/	389	GTO 02	445	2				
334	LN	390	LBL 01	446	/				
335	RCL 06	391	"FATE :"	447	RTN				
336	FC? 10	392	XEQ 00	448	LBL 19				

EXAMPLE 3.12

(See also page 83-84 in manual)

Data from Appendix I,
Tab. 5.4
For constants, see FB 11

```

* FB 12 *

CONSTANTS :
L<00> : 30.90
D      : 1.00
K      : 0.510
L<MIN> : 4.00
L<MAX> : 26.00
dL     : 2.00

CATCH CURVE :

L <5.00> : 5.00
LN <Y> : 3.497
R. AGE : 0.346

L <7.00> : 29.00
LN <Y> : 5.174
R. AGE : 0.504

L <9.00> : 114.00
LN <Y> : 6.455
R. AGE : 0.675

L <11.00> : 161.00
LN <Y> : 6.705
R. AGE : 0.863

L <13.00> : 143.00
LN <Y> : 6.480
R. AGE : 1.071

L <15.00> : 118.00
LN <Y> : 6.169
R. AGE : 1.303

L <17.00> : 61.00
LN <Y> : 5.375
R. AGE : 1.566

L <19.00> : 50.00
LN <Y> : 5.020
R. AGE : 1.871

L <21.00> : 32.00
LN <Y> : 4.388
R. AGE : 2.232

L <23.00> : 17.00
LN <Y> : 3.528
R. AGE : 2.674

L <25.00> : 4.00
LN <Y> : 1.785
R. AGE : 3.247

L <27.00> : 4.00
LN <Y> : 1.358
R. AGE : 4.058

FOR CURVE :
L <P1> : 13.00
L <P2> : 27.00

Z <1.> ESTIMATE :
rt2 : 0.974
a : 8.406
b : -1.839
Z : 1.839

Z <2.> ESTIMATE :
rt2 : 0.968
a : 7.814
b : -1.850
Z : 1.850

Z <3.> ESTIMATE :
rt2 : 0.968
a : 7.807
b : -1.849
Z : 1.849

```

3.13: PROGRAM DESCRIPTION FB 13

Z and K from Mean Lengths

As demonstrated by Ebert (1973), estimates of K and Z can be obtained from two mean lengths, a value of $L(\infty)$, a length at recruitment (L_r) and times t_1 and t_2 (corresponding to the mean lengths) by solving two equations, which become, in terms of the generalized VBGF

$$\frac{N \frac{e^{-ZX}}{e^{-ZX}} - b \frac{N e^{-(KD(t_1 + X) + ZX)}}{e^{-(KD(t_1 + X) + ZX)}}}{N \frac{e^{-ZX}}{e^{-ZX}}} = \frac{L_1^D}{L(\infty)^D} \quad \dots 1)$$

$X = 0$ $X = 0$

and

$$\frac{N \frac{e^{-ZX}}{e^{-ZX}} - b \frac{N e^{-(KD(t_2 + X) + ZX)}}{e^{-(KD(t_2 + X) + ZX)}}}{N \frac{e^{-ZX}}{e^{-ZX}}} = \frac{L_2^D}{L(\infty)^D} \quad \dots 2)$$

$X = 0$ $X = 0$

where $b = L_r / L(\infty) - (L_r / L(\infty))$, while N is the integer portion of Y when $Y = \frac{1}{Z} \left((-\log_e 0.00001) / Z \right)$. As shown by Saila and Lough (1981) these equations have an explicit solution for K, i.e.,

$$K = \ln \left[\frac{L(\infty)^D - L_2^D}{L(\infty)^D - L_1^D} \right] \cdot \frac{1}{(t_1 - t_2)^D} \quad \dots 3)$$

Once K has been calculated, the value of Z is obtained using a very simplified version of the algorithm given in Ebert (1973, p. 285).

Operating Limits and Warnings

The values of the times t_1 and t_2 are computed for t_1 and t_2 ($t_{1,2}$) using the formulas

CASE I ($R > SM$): $t_{1,2} = 1 - (1/12 (R - SM))$

CASE II ($R \leq SM$): $t_{1,2} = 1/12 (R - SM)$

with both the month of recruitment [R] and sampling month [SM] being expressed as numerals [i.e. Jan. = 1, Feb. = 2, etc.]

For computational reason, the 15th day of a month is assumed to be the sampling day. If the true sampling day differs markedly from the 15th, express the deviation of the actual date from the next lower "mid-month-point" (15th) as a fraction of 1, and add it to the numeral for the lower month. (e.g: 5 May = 4.6)

The values of t_1 and t_2 estimated internally given sampling dates account for and correct the erroneous definition of these quantities in Ebert (1973) (see Appendix II).

Iterating time can be quite long when dealing with low values of Z ; it saves time therefore, to enter initial guesses that are assumed higher than the true values (rather than the reverse).

A time period of exactly one year between the sampling months for L_1 and L_2 will cause a "DATA ERROR" message.

FB 13: Z AND K FROM MEAN LENGTHS

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM (DISPLAY OF MENU) - ESTIMATION OF MEAN SIZE AND ITS STANDARD ERROR - Z AND K FROM MEAN LENGTH - MENU - INITIALIZE - REVIEW RESULTS			* FB 13 * MENU MEAN SIZE: A Z AND K : B MENU : C INITIAL. : c REV. RES.: E
1.	<u>ESTIMATION OF MEAN SIZE AND ITS STANDARD ERROR</u> PRESS		A	FOR LOW. SIZE: LOW CL. LIM. ?
1.1	ENTER THE LOWER CLASS LIMIT OF THE LOWEST SIZE CONSIDERED,	S'	R/S	CL. INTERVAL ?
1.2	ENTER CLASS INTERVAL	ΔS	R/S	NO. OF ROWS ?
1.3	ENTER NUMBER OF ROWS	k	R/S	N<S. _i > ?
1.4	ENTER FREQUENCIES, STARTING FROM THE LOWEST CLASS (ENTER ZERO WHEN APPROPRIATE)	N _i (i=1..k)	R/S	N<S. _{i+1} > ?
1.5	(DISPLAY OF RESULTS)			MEAN: (x)
1.5.1	MEAN SIZE			
1.5.2	STANDARD DEVIATION OF THE SIZE VALUES			S.D.: (x)
1.5.3	STANDARD ERROR OF THE MEAN			S.E.: (x)
1.5.4	TOTAL NUMBER (N)			ΣN : (x)
1.6	IF YOU WANT TO ADD FREQUENCIES OF SIZE CLASSES HIGHER THAN THE ONE CONSIDERED LAST, PRESS		R/S	ADD FREQY.? YES: 1, NO: 0
1.6.1	ENTER "1"	1	R/S	NO. OF ROWS ?
1.6.2	AND CONTINUE AT STEP 1.3			
1.7	FOR A NEW SET OF DATA, PRESS AND SELECT FROM THE MENU		f c	* FB 13 *
2.	<u>Z AND K FROM MEAN LENGTH</u> PRESS		B	ENTER: D ?
2.1	AND ENTER:			
2.1.1	D	D	R/S	L<00> ?

FB 13: Z AND K FROM MEAN LENGTHS

USER INSTRUCTIONS (cont.)

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
2.1.2	$L_{(\infty)}$	$L_{(\infty)}$	R/S	L<R> ?
2.1.3	LENGTH AT RECRUITMENT	L_r	R/S	L<1> ?
2.1.4	MEAN LENGTH AT t_1	L_1	R/S	L<2> ?
2.1.5	MEAN LENGTH AT t_2	L_2	R/S	ENTER MONTH:
2.2	INDICATE - BY USING A NUMERAL (1-12)-THE MONTH OF:			A: RECRUITM. ?
2.2.1	RECRUITMENT	M_r	R/S	B: L<1>-SPL ?
2.2.2	THE MONTH CORRESP. TO SAMPLE NO. 1	M_1	R/S	T<1>: (x)
2.2.2.1	(DISPLAY OF t_1 - VALUE)			C: L<2>-SPL ?
2.2.3	THE MONTH CORRESP. TO SAMPLE NO. 2	M_2	R/S	T<2>: (x)
2.2.3.1	(DISPLAY OF t_2 -VALUE)			Z<INIT.> ?
2.2.4	ENTER INITIAL ² VALUE FOR "Z"	Z INITIAL	R/S	Z<1>: (x)
				Z<2>: (x)
				:
2.3	(RESULTS)			:
2.3.1	K			K: (x)
2.3.2	FINAL ESTIMATE OF Z			Z<FIN.>: (x)
2.4	FOR A NEW SET OF DATA, DO AND SELECT FROM THE MENU		f c	MENU:

REGISTERS, STATUS, FLAGS

PROGR. NAME: FB 13 (Z and K from Mean Lengths)

STATUS : REG. (PROGR.): 125
 SIZE (MIN.) : 015 SIZE (MAX.): -

FLAGS : 9, 10

ASSIGNMENTS:

A: GENERAL COMMANDS

B: SPECIAL COMMANDS

INITIALIZE : (f)c
 REVIEW RESULTS : E

MEAN SIZE IN SAMPLE : A
 Z/K FROM MEAN LENGTH : B

REGISTERS :

SUB-

PROGR.:	A	B	A	B
00 :	[u]	Z<FIN>		
01 :	-	[u]	RESULTS	
02 :	[u]	[u]	ARE	
03 :	[u]	[u]	STORED	
04 :	[u]	[u]	IN	
05 :	[u]	[u]	X-REGISTER	
06 :	-	[u]		
07 :	[u]	[u]		
08 :	[u]	[u]		
09 :	[u]	[u]		
10 :		K*D		
11 :		D		
12 :		[u]		
13 :		[u]		
14 :		[u]		

Program Listing

(FB 13)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01	LBL "FB 13"	57	FIX 1	113	CF 21	169	XEQ 03	225	*
02	LBL C	58	LBL "K"	114	STOP	170	STO 09	226	X>0?
03	CF 21	59	"H<"	115	"ADD FREQU. ?"	171	1	227	-
04	BEEP	60	ARCL 07	116	AVIEW	172	XEQ 05	228	ABS
05	" * FB 13 *"	61	"H> ?"	117	PSE	173	2	229	FIX 3
06	AVIEW	62	PROMPT	118	"YES. 1, NO. 0"	174	"C"	230	RND
07	SREG 00	63	STO 03	119	PROMPT	175	XEQ 03	231	RTN
08	SF 27	64	ST+ 04	120	X=0?	176	2	232	LBL 05
09	CF 21	65	RCL 02	121	GTO C	177	XEQ 05	233	FIX 0
10	CF 09	66	X+2	122	GTO "M"	178	RDN	234	"T<"
11	PSE	67	RCL 03	123	LBL B	179	X<> 09	235	ARCL X
12	LBL C	68	*	124	CF 21	180	RCL 09	236	"H> : "
13	"MENU :"	69	ST+ 05	125	"ENTER :"	181	-	237	FIX 3
14	AVIEW	70	RCL 02	126	AVIEW	182	STO 10	238	ARCL Y
15	PSE	71	RCL 03	127	FIX 0	183	"Z <INIT.> ?"	239	AVIEW
16	"MEAN SIZE : A"	72	*	128	CF 10	184	PROMPT	240	FIX 0
17	AVIEW	73	ST+ 09	129	CLRG	185	STO 12	241	PSE
18	PSE	74	RCL 08	130	PSE	186	RCL 03	242	PSE
19	"Z AND K : B"	75	ST+ 07	131	">DK ?"	187	RCL 02	243	RTN
20	AVIEW	76	ST+ 02	132	PROMPT	188	-	244	LBL "Z"
21	PSE	77	ISG 00	133	STO 11	189	RCL 03	245	CL2
22	"MENU : C"	78	GTO "K"	134	3	190	/	246	STO 12
23	AVIEW	79	GTO E	135	ENTER+	191	STO 08	247	FIX 0
24	PSE	80	LBL "L"	136	"00"	192	RCL 00	248	"Z<"
25	"INITIAL. : c"	81	RCL 09	137	ASTO X	193	RCL 03	249	ARCL 14
26	AVIEW	82	RCL 04	138	XEQ 04	194	/	250	FIX 3
27	PSE	83	/	139	ENTER+	195	STO 06	251	"H> : "
28	"REV. RES. : E"	84	"MEAN"	140	"R"	196	RCL 02	252	ARCL Y
29	AVIEW	85	FIX 2	141	ASTO X	197	RCL 00	253	AVIEW
30	RTN	86	XEQ 10	142	XEQ 04	198	-	254	TOPE 7
31	LBL A	87	PSE	143	1	199	RCL 03	255	1
32	"FOR LOW. SIZE:"	88	X+2	144	XEQ 04	200	RCL 01	256	ST+ 14
33	AVIEW	89	RCL 05	145	2	201	-	257	RCL 07
34	CLRG	90	RCL 04	146	XEQ 04	202	/	258	LN
35	SF 10	91	/	147	GTO 01	203	LN	259	CHS
36	CF 21	92	X<>Y	148	LBL 04	204	RCL 10	260	RCL 12
37	PSE	93	-	149	"L <"	205	/	261	/
38	"LOW. CL. LIM. ?"	94	SORT	150	ARCL Y	206	STO 10	262	1
39	PROMPT	95	FIX 3	151	"H> ?"	207	1 E-4	263	+
40	STO 07	96	SF 13	152	PROMPT	208	STO 07	264	INT
41	"CL. INTERVAL?"	97	"S.D."	153	RCL 11	209	1	265	STO 13
42	PROMPT	98	XEQ 10	154	Y+X	210	STO 14	266	LBL "N"
43	STO 08	99	PSE	155	STO IND Z	211	RCL 12	267	RCL 12
44	2	100	RCL 04	156	RCL Z	212	GTO "Z"	268	RCL 03
45	/	101	SORT	157	1	213	LBL 03	269	*
46	+	102	/	158	-	214	"H. L<"	270	STO 00
47	STO 02	103	"S.E."	159	RTN	215	ARCL X	271	CHS
48	LBL "M"	104	XEQ 10	160	LBL 01	216	"H>-SPL. ?"	272	E+X
49	"NO. OF ROWS ?"	105	CF 13	161	"ENTER MONTH ."	217	PROMPT	273	ST+ 01
50	PROMPT	106	PSE	162	AVIEW	218	STO 05	274	RCL 03
51	3	107	RCL 04	163	PSE	219	1	275	*
52	10+X	108	FIX 0	164	"A: RECRUITM. ?"	220	12	276	ST+ 02
53	/	109	"ZN"	165	PROMPT	221	1/X	277	RCL 09
54	1	110	XEQ 10	166	STO 04	222	RCL 04	278	RCL 03
55	+	111	SF 21	167	1	223	RCL 05	279	+
56	STO 00	112	ADV	168	"B"	224	-	280	RCL 10

Program Listing

(FB 13 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
281 *		337 ABS		393 SF 09					
282 RCL 00		338 X<=Y?		394 CF 21					
283 +		339 GTO E		395 .END.					
284 CHS		340 RCL 00							
285 E+X		341 GTO "Z"							
286 ST+ 04		342 GTO 01							
287 RCL 03		343*LBL E							
288 *		344 BEEP							
289 ST+ 05		345 FC? 55							
290 RCL 03		346 GTO 01							
291 RCL 13		347 FC? 09							
292 X=Y?		348 XEQ 11							
293 GTO 01		349*LBL 01							
294 1		350 FS? 10							
295 ST+ 03		351 GTO "L"							
296 GTO "N"		352 RCL 10							
297*LBL 01		353 RCL 11							
298 RCL 01		354 /							
299 RCL 04		355 FIX 3							
300 RCL 08		356 "K"							
301 *		357 XEQ 10							
302 -		358 PSE							
303 RCL 01		359 PSE							
304 /		360 RCL 00							
305 RCL 06		361 "Z<FIN.)"							
306 -		362 XEQ 10							
307 STO 00		363 STOP							
308 RCL 06		364 GTO C							
309 1		365*LBL 10							
310 -		366 "F : "							
311 RCL 02		367 FS? 55							
312 *		368 GTO 01							
313 RCL 05		369 ARCL X							
314 RCL 08		370 AVIEW							
315 *		371 PSE							
316 +		372 RTN							
317 RCL 00		373*LBL 01							
318 X<>Y		374 SF 21							
319 /		375 ACA							
320 CHS		376 ACX							
321 RCL 12		377 PRBUF							
322 +		378 CF 21							
323 STO 00		379 RTN							
324 X>0?		380*LBL 11							
325 GTO 01		381 SF 21							
326 RCL 12		382 ADV							
327 .9		383 ADV							
328 *		384 SF 12							
329 STO 00		385 "FB 13"							
330*LBL 01		386 ACA							
331 RCL 07		387 PRBUF							
332 10		388 "RESULTS"							
333 *		389 ACA							
334 RCL 12		390 PRBUF							
335 RCL 00		391 CF 12							
336 -		392 ADV							

EXAMPLE 3.13

(See also page 86 in manual)

Data from Appendix I,
Tab. 5.8

**FB 13
RESULTS**

MEAN : 8.58
s.d. : 1.556
s.e. : 0.083
ZN : 350.

MEAN : 11.07
s.d. : 1.412
s.e. : 0.100
ZN : 198.

K : 0.748
Z(FIN.) : 3.186

[note that the estimates of K and Z in the last example differ slightly from those in manual (see ref. to correction for p. 86 in Appendix II)].

3.14: PROGRAM DESCRIPTION FB 14

F and M from Tagging-Recapture Data

Total mortality (Z) may be estimated from the equation

$$\ln N_r = a + br' \quad \dots 1)$$

where N_r is the number of recoveries per time interval, where r' is the coded time interval (starting with $r' = 0$, then $r' = 1, 2, 3$, etc.), and where b , with sign changed, is equal to Z .

Total mortality may then be split into F and M by means of the expression

$$F = \frac{e^a Z}{N_o (1 - e^{-Z})} \quad \dots 2)$$

where N_o is the total number of fish tagged and released and " a " is the intercept of equation (1) (Gulland, 1969).

Operating Limits and Warnings

Gulland (1969, section 6) should be consulted for details and sources of bias and errors.

FB 14: F AND M FROM TAGGING-RECAPTURE DATA

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM			* FB 14 * TAGGING TIME BASE IN: Y/M/D ? (1,2,3):
1.	INDICATE WHETHER THE TIME INTERVALS OF THE TAGGING EXPERIMENT ARE GIVEN IN YEARS ("1"), MONTHS ("2") OR DAYS ("3")	1,2 OR 3	R/S	NO. OF ROWS ?
2.	ENTER TOTAL NUMBER OF ROWS	k	R/S	ENTER: N<R=(r)> ?
3.	FOR INTERVALS $r=0,1,..k-1$ ENTER NO. OF RECOVERIES	N_r	R/S	N = <R=(r+1)> ?
4.	DISPLAY OF RESULTS:			
4.1	COEFFICIENT OF DETERMINATION [r^2]			R^2 : (x)
4.2	INTERCEPT [a]			a : (x)
4.3	TOTAL MORTALITY [Z] PER YEAR			Z : (x)
5.	SPLITTING Z INTO F AND M			* F AND M * N <0> ?
5.1	ENTER TOTAL NUMBER OF FISH TAGGED	N_o	R/S	
6.	DISPLAY OF RESULTS:			
6.1	FISHING MORTALITY [F] PER YEAR			F : (x)
6.2	NATURAL MORTALITY [M] PER YEAR			M : (x)
7.	TO REVIEW RESULTS, PRESS		E	R^2 : (x)
8.	FOR A NEW SET OF DATA, PRESS		f c	* FB 14 *

REGISTERS, STATUS, FLAGS

PROGR. NAME: FB 14 (F and M from Tagging-Recapture Data)

STATUS : REG. (PROGR.): 56
SIZE (MIN.) : 016 SIZE (MAX.): -

FLAGS : 1 - 3, 8, 9

ASSIGNMENTS:

A: GENERAL COMMANDS

B: SPECIAL COMMANDS

INITIALIZE : (f)c

REVIEW RESULTS : E

REGISTERS :

SUB-
PROGR.:

00 : [u]
01 : F
02 : -
03 : -
04 : r²
05 : a
06 : b
07 : Z
08 : -
09 : -
10 : [u]
11 : [u]
12 : [u]
13 : [u]
14 : [u]
15 : [u]

Program Listing

(FB 14)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01	LBL "FB 14"	57	X12	113	-	169	ADV		
02	LBL c	58	RCL 13	114	*	170	LBL 01		
03	CF 21	59	RCL 12	115	RCL 06	171	ACA		
04	BEEP	60	X12	116	CHS	172	PRBUF		
05	" * FB 14 *"	61	RCL 15	117	RCL 05	173	CF 12		
06	XEQ 11	62	/	118	E+X	174	CF 21		
07	SREG 10	63	-	119	*	175	RTN		
08	SF 27	64	/	120	X<>Y	176	LBL "X"		
09	CLRG	65	RCL 11	121	/	177	FS? 01		
10	CF 01	66	RCL 10	122	XEQ "X"	178	1		
11	CF 02	67	X12	123	*	179	FS? 02		
12	CF 03	68	RCL 15	124	STO 01	180	12		
13	CF 08	69	/	125	SF 08	181	FS? 03		
14	CF 09	70	-	126	LBL 01	182	365		
15	"TAGGING"	71	ST/ 06	127	RCL 07	183	.END.		
16	XEQ 11	72	/	128	RCL 01				
17	TONE 7	73	STO 04	129	"F "				
18	"TIME BASE IN"	74	RCL 12	130	XEQ 10				
19	AVIEW	75	RCL 06	131	-				
20	PSE	76	RCL 10	132	"M "				
21	PSE	77	*	133	XEQ 10				
22	"Y/M/D? (1,2,3,)"	78	-	134	STOP				
23	PROMPT	79	RCL 15	135	GTO E				
24	SF IND X	80	/	136	LBL 10				
25	"NO. OF ROWS ?"	81	STO 05	137	"H . "				
26	PROMPT	82	RCL 06	138	FS? 55				
27	"ENTER :"	83	CHS	139	GTO 01				
28	AVIEW	84	XEQ "X"	140	ARCL X				
29	1	85	*	141	AVIEW				
30	-	86	STO 07	142	PSE				
31	3	87	LBL E	143	PSE				
32	10+X	88	XEQ 05	144	RTN				
33	/	89	FIX 3	145	LBL 01				
34	ST+ 00	90	SF 13	146	SF 21				
35	PSE	91	RCL 04	147	ACA				
36	FIX 0	92	"R12"	148	ACX				
37	LBL 04	93	XEQ 10	149	PRBUF				
38	RCL 00	94	RCL 05	150	CF 21				
39	INT	95	"a "	151	RTN				
40	"N <R="	96	XEQ 10	152	LBL 11				
41	ARCL X	97	CF 13	153	AVIEW				
42	"H> ?"	98	RCL 07	154	PSE				
43	PROMPT	99	"Z "	155	FC? 55				
44	LN	100	XEQ 10	156	RTN				
45	X<>Y	101	PSE	157	SF 21				
46	S+	102	FS? 08	158	ADV				
47	ISG 00	103	GTO 01	159	ADV				
48	GTO 04	104	TONE 7	160	SF 12				
49	RCL 14	105	" * F AND M *"	161	GTO 01				
50	RCL 10	106	AVIEW	162	LBL 05				
51	RCL 12	107	PSE	163	"RESULTS"				
52	*	108	"N<D> ?"	164	BEEP				
53	RCL 15	109	PROMPT	165	AVIEW				
54	/	110	1	166	FC? 55				
55	-	111	RCL 06	167	RTN				
56	STO 06	112	E+X	168	SF 21				

EXAMPLE 3.14

(See also page 88 in manual)

Data from Appendix I,
Tab. 5.10

*** FB 14 ***

TAGGING

RESULTS

r12 : 0.964
a : 7.427
Z : 15.056
F : 6.771
M : 8.285

[note that results, i.e. Z, F and M values, are expressed on a yearly basis, and hence can be compared with the corresponding estimates in Example 5.13, p. 88 of the manual only after the latter estimates, expressed on a monthly basis, have been multiplied by 12]

3.15: PROGRAM DESCRIPTION FB 15

Independent Estimates of M

As demonstrated in Pauly (1980c), reasonable estimates of M can be obtained from the empirical relationships

$$\log_{10} M = -0.2107 - 0.0824 \log_{10} W_{\infty} + 0.6757 \log_{10} K \\ + 0.4627 \log_{10} \bar{T} \quad \dots 1)$$

and

$$\log_{10} M = -0.0066 - 0.279 \log_{10} L_{\infty} + 0.6543 \log_{10} K \\ + 0.4634 \log_{10} \bar{T} \quad \dots 2)$$

where W_{∞} , L_{∞} and K are parameters of the special von Bertalanffy Growth Formula, and $\bar{T}$ the mean annual environmental temperature of the stock in question.

W_{∞} should be expressed in g live weight, L_{∞} in cm total length, K put on an annual basis and $\bar{T}$ expressed in °C.

An internal routine transforms, for temperatures lower than 3.5 °C (down to -2 °C), the $\bar{T}$ values to their corresponding "physiologically effective temperature", T' (see Pauly 1980c, Fig. 1). The latter being always > 0 °C, negative temperature (down to -2 °C) can be used with FB 15.

Operating Limits and Warnings

- 1) In the case of the Clupeidae (Herrings, Sardines, etc.) the estimates of M provided by expressions (1) and (2) tend to be too high, and should be reduced by a factor of 0.8 to 0.6.
- 2) In the case of polar fishes (occurring at temp. < 3.5 °C) the estimates of M tend to be too low, and should be increased by a factor of 1.3 (see Pauly 1980c).

FB 15: INDEPENDENT ESTIMATES OF M

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM			* FB 15 *
1.	DISPLAY OF MENU			MENU
1.1	ESTIMATE OF M USING L _∞			M<LENGTH>: A
1.2	ESTIMATE OF M USING W _∞			M<WEIGHT>: B
1.3	DISPLAY OF MENU			MENU : C
1.4	INITIALIZE			INITIAL : c
1.5	REVIEW RESULT			REV. RES.: E
2.	CHOOSE:			
2.1	M FROM LENGTH DATA, DO		A	L<00> ?
2.1.1	ENTER L _∞	L _∞	R/S	K ?
2.2	M FROM WEIGHT DATA, DO		B	W<00> ?
2.2.1	ENTER W _∞	W _∞	R/S	K ?
3.	ENTER K	K	R/S	T<MEAN> ?
4.	ENTER MEAN ENVIRONMENTAL TEMPERATURE	$\bar{T}$	R/S	<RESULTS>
5.	DISPLAY OF RESULTS ^{a)}			
5.1	NATURAL MORTALITY [M]			M: (x)
6.	FOR NEW SET OF DATA, DO		f c	* FB 15 *

a) NOTE: NO PRINT OUT.

REGISTERS, STATUS, FLAGS

PROGR. NAME: FB 15 (Independent Estimates of M)

STATUS : REG. (PROGR.): 40
 SIZE (MIN.) : 005 SIZE (MAX.): -

FLAGS : -

ASSIGNMENTS:

A: <u>GENERAL COMMANDS</u>	B: <u>SPECIAL COMMANDS</u>
INITIALIZE : (f)c	M FROM LENGTH : A
REVIEW RESUTLS : E	M FROM WEIGHT : B
RECALL MENU : C	

REGISTERS :

00 : -
01 : M
02 : -
03 : [u]
04 : [u]

Program Listing

(FB 15)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01	LBL "FB 15"	57	RCL 03						
02	LBL c	58	*						
03	CF 21	59	+						
04	BEEP	60	"T (MEAN) ?"						
05	" * FB 15 *"	61	PROMPT						
06	AVIEW	62	3.5						
07	SF 27	63	X>Y?						
08	CLRG	64	XEQ 09						
09	PSE	65	RDN						
10	LBL C	66	LOG						
11	"MENU :"	67	RCL 04						
12	AVIEW	68	*						
13	PSE	69	+						
14	"M (LENGTH): A"	70	101X						
15	AVIEW	71	STO 01						
16	PSE	72	LBL E						
17	"M (WEIGHT): B"	73	BEEP						
18	AVIEW	74	FIX 2						
19	PSE	75	"M : "						
20	"MENU : C"	76	ARCL 01						
21	AVIEW	77	PROMPT						
22	PSE	78	GTO E						
23	"INITIAL. : c"	79	LBL 09						
24	AVIEW	80	RDN						
25	PSE	81	.13827						
26	"REV. RES.: E"	82	*						
27	AVIEW	83	CHS						
28	RTH	84	.07661						
29	LBL B	85	+						
30	.6757	86	E1X						
31	STO 03	87	E1X						
32	.4627	88	ENTER↑						
33	STO 04	89	.END.						
34	-.2107								
35	ENTER↑								
36	.0824								
37	"H"								
38	GTO 01								
39	LBL A								
40	.6543								
41	STO 03								
42	.4634								
43	STO 04								
44	-.0066								
45	ENTER↑								
46	.279								
47	"L"								
48	LBL 01								
49	"T (00) ?"								
50	PROMPT								
51	LOG								
52	*								
53	-								
54	"K ?"								
55	PROMPT								
56	LOG								

EXAMPLE 3.15

- I. Estimate M in Selaroides leptolepis from the Gulf of Thailand
($\bar{T} = 27^{\circ}\text{C}$). The growth parameters are:

$$L_{\infty} = 20 \text{ cm}$$

$$K = 1.16 \text{ (per year)}$$

Result: $M = 2.17$

(adapted from Example 5.14, p. 89 in manual)

- II. Estimate of M in Lutjanus sanguineus from the South China Sea
($\bar{T} = 28^{\circ}\text{C}$). The growth parameters are:

$$W_{\infty} = 12226 \text{ g}$$

$$K = 0.154 \text{ (per year)}$$

Result: $M = 0.37$

(adapted from Example 8.2, p. 124 in manual)

3.16: PROGRAM DESCRIPTION FB 16

Population Size (Petersen's Method)

Jones (1977, Table 1) gives the following equations for estimating population size (N) and its variance (var N):

Type of sampling	Estimates of		Reference
	population size	standard deviation of N	
Direct	$N = \frac{Tn}{m}$	$s.e._N = \left(\frac{T^2 n(n-m)}{m^3} \right)$	(A) Bailey (1951)
Direct	$N = \frac{T(n+1)}{m+1}$	$s.e._N = \left(\frac{T^2 (n+1)(n-m)}{(m+1)^2 (m+2)} \right)$	(B) Bailey (1952)
Direct	$N = \frac{(T+1)(n+1)}{m+1}$	$s.e._N = \left(N^2 \left[\frac{N}{nT} + 2 \left(\frac{N}{nT} \right) + \left(6 \frac{N}{nT} \right)^3 \right]^{\frac{1}{2}} \right)$	(C) Chapman (1951) Schaefer (1951)
Inverse	$N = \frac{n(T+1)}{m} - 1$	$s.e._N = \left(\frac{(T-m+1)(N+1)(N-T)}{m(T+2)} \right)^{\frac{1}{2}}$	(D) Bailey (1951) Chapman (1952)

where T is the number of fish tagged (one tagging occasion), n is the total number of individuals recaptured during the entire experiment, and m is the number of tagged individuals recovered during the experiment.

Each of the methods (A-D) given here has its advantages and disadvantages and the original publications should be consulted for details, as well as Jones (1977) and Ricker (1975).

Operating Limits and Warnings

"Direct" sampling means that sampling is continued until a predetermined sample size (n) is obtained, "inverse" sampling means that sampling is carried out until a predetermined number of tagged animals (m) is obtained. This distinction should be considered when computing N.

FB 16: POPULATION SIZE [PETERSEN'S METHOD]

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM			* FB 16 * ENTER:
1.	ENTER:			T ?
1.1	TOT. NO. OF FISH TAGGED [T]	T	R/S	N ?
1.2	TOT. NO. OF FISH RECAPTURED	n	R/S	M ?
1.3	TOT. NO. OF TAGGED FISH RECAPTURED	m	R/S	SELECT: A,B,F,G
2.	SELECT METHOD:			
2.1	BAILEY [1951]		A	<RESULTS>
2.2	BAILEY [1952]		B	<RESULTS>
2.3	CHAPMAN/SCHAEFER		F	<RESULTS>
2.4	BAILEY/CHAPMAN		G	<RESULTS>
3.	DISPLAY OF RESULTS			
3.1	POPULATION SIZE [N]			N : (x)
3.2	STANDARD ERROR OF N [s.e.]			S.E. : (x)
4.	FOR ANOTHER METHOD, GO TO STEP 2.			
5.	FOR A NEW SET OF DATA, DO AND GO TO STEP 1.		f c	* FB 16 *

REGISTERS, STATUS, FLAGS

PROGR. NAME: FB 16 (Population Size [Petersen's Method])

STATUS : REG. (PROGR.): 64
SIZE (MIN.) : 008 SIZE (MAX.): -

FLAGS : -

ASSIGNMENTS:

A: GENERAL COMMANDS

B: SPECIAL COMMANDS

INITIALIZE : (f)c

CASE <A> : A

CASE : B

CASE <C> : F

CASE <D> : G

REGISTERS :

SUB- PROGR.:	A	B	F	G
00 :	-	-	-	-
01 :	T	T	T	T
02 :	n	n	n	n
03 :	m	m	m	m
04 :	N	N	N	N
05 :	s.e.	s.e.	s.e.	s.e.
06 :	[u]	[u]	[u]	[u]
07 :	[u]	[u]	[u]	[u]

Program Listing

(FB 16)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01	LBL "FB 16"	57	/	113	*	169	STO 05	225	CF 12
02	LBL c	58	SORT	114	STO 06	170	"D"	226	CF 21
03	CF 21	59	STO 05	115	/	171	ASTO X	227	RTN
04	BEEP	60	"A"	116	RCL 04	172	LBL e	228	LBL 13
05	* * FB 16 *	61	ASTO X	117	RCL 06	173	FC? 55	229	FS? 55
06	AVIEW	62	GTO e	118	/	174	GTO E	230	XEQ 01
07	CLRG	63	LBL B	119	X*2	175	SF 21	231	"F ?"
08	PSE	64	RCL 01	120	2	176	ADV	232	PROMPT
09	FS? 55	65	RCL 02	121	*	177	"CASE >"	233	FS? 55
10	XEQ 11	66	1	122	+	178	ARCL X	234	XEQ 02
11	"ENTER :"	67	+	123	RCL 04	179	"F<"	235	RTN
12	AVIEW	68	STO 06	124	RCL 06	180	ACA	236	LBL 01
13	TONE 7	69	*	125	/	181	PRBUF	237	SF 21
14	FS? 55	70	RCL 03	126	3	182	CF 21	238	ACA
15	XEQ 12	71	1	127	Y*X	183	LBL E	239	CF 21
16	PSE	72	+	128	6	184	FIX 0	240	RTN
17	"T "	73	STO 07	129	*	185	RCL 04	241	LBL 02
18	XEQ 13	74	/	130	+	186	"N "	242	SF 21
19	STO 01	75	STO 04	131	RCL 04	187	XEQ 10	243	CLA
20	SF 13	76	RCL 01	132	X*2	188	RCL 05	244	"F : "
21	"*N*"	77	X*2	133	*	189	SF 13	245	ACA
22	XEQ 13	78	RCL 06	134	SORT	190	"S,E."	246	ACX
23	STO 02	79	*	135	STO 05	191	XEQ 10	247	PRBUF
24	"***"	80	RCL 02	136	"C"	192	CF 13	248	CF 21
25	XEQ 13	81	RCL 03	137	ASTO X	193	STOP	249	.END.
26	STO 03	82	-	138	GTO e	194	GTO E		
27	CF 13	83	*	139	LBL G	195	LBL 10		
28	FC? 55	84	RCL 07	140	RCL 02	196	"F : "		
29	GTO 01	85	X*2	141	RCL 01	197	FS? 55		
30	SF 21	86	RCL 03	142	1	198	GTO 01		
31	ADV	87	2	143	+	199	ARCL X		
32	"RESULTS"	88	+	144	*	200	AVIEW		
33	ACA	89	*	145	RCL 03	201	PSE		
34	PRBUF	90	/	146	/	202	PSE		
35	CF 21	91	SORT	147	1	203	RTN		
36	LBL 01	92	STO 05	148	-	204	LBL 01		
37	"SELECT: A,B,F,G"	93	"B"	149	STO 04	205	SF 21		
38	PROMPT	94	ASTO X	150	1	206	ACA		
39	LBL A	95	GTO e	151	+	207	ACX		
40	RCL 01	96	LBL F	152	RCL 01	208	PRBUF		
41	RCL 02	97	RCL 01	153	RCL 03	209	CF 21		
42	*	98	1	154	1	210	RTN		
43	RCL 03	99	+	155	+	211	LBL 11		
44	/	100	RCL 02	156	-	212	SF 21		
45	STO 04	101	1	157	*	213	ADV		
46	RCL 01	102	+	158	RCL 04	214	ADV		
47	X*2	103	*	159	RCL 01	215	SF 12		
48	RCL 02	104	RCL 03	160	-	216	"FB 16"		
49	*	105	1	161	*	217	GTO 01		
50	RCL 02	106	+	162	RCL 03	218	LBL 12		
51	RCL 03	107	/	163	RCL 01	219	SF 21		
52	-	108	1	164	2	220	ADV		
53	*	109	-	165	+	221	"CONSTANTS :"		
54	RCL 03	110	STO 04	166	*	222	LBL 01		
55	3	111	RCL 01	167	/	223	ACA		
56	Y*X	112	RCL 02	168	SORT	224	PRBUF		

EXAMPLE 3.16

(See also p. 96 in manual)

Data from Appendix I,
Tab. 6.1

FB 16

CONSTANTS :

T : 984.

n : 3,253.

*** : 68.

RESULTS

CASE >A<

N : 47,073.

s.e. : 5,648.

CASE >B<

N : 46,485.

s.e. : 5,487.

CASE >C<

N : 46,451.

s.e. : 5,680.

CASE >D<

N : 47,120.

s.e. : 5,447.

3.17: PROGRAM DESCRIPTION FB 17

Leslie's Equation

When a population is fished strongly enough to significantly reduce the catch/effort, and when the stock size reduction occurs fast enough for the effects of recruitment, mortality and immigration to be ignored, we have in Leslie's formulation

$$\frac{C_t}{f_t} = q N_0 - q \Sigma t \quad \dots 1)$$

which states that catch/effort (C_t/f_t) in a given time period t , plotted against the cumulative catch up to that period (Σt) gives a straight line, the slope of which, with sign changed, is an estimate of the catchability coefficient (q) and the intercept of which ($q N_0$), divided by q , gives an estimate of the unfished stock size (N_0). When the special case applies that effort is, or can be assumed to be constant for all time periods, the C_t/f_t values can be replaced by C_t , in which case the slope of the line provides an estimate of F instead of q .

Leslie's equation, as shown by Ricker (1975, p. 149-155) is simpler and often more appropriate than the related De Lury equation, also used to estimate N_0 and q from cumulative catch data.

FB 17: LESLIE'S EQUATION

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM			* FB 17 *
1.	DISPLAY OF MENU			MENU
1.1	GENERAL CASE: CHANGING EFFORT			CH. EFFORT : A
1.2	SPECIAL CASE: CONSTANT EFFORT			CST. EFFORT: B
1.3	MENU			MENU : C
1.4	INITIALIZE			INIT. : c
1.5	REVIEW RESULTS			REV. RES. : E
2.	SELECT CASE:			
2.1	GENERAL CASE: PRESS		A	NO. OF ROWS ?
2.1.1	ENTER TOTAL NUMBER OF ROWS	k	R/S	ENTER:
2.1.2	FOR N = 1,2, ... k, ENTER:			C<n> ?
2.1.2.1	CATCH	C_t	R/S	F<n> ?
2.1.2.2	EFFORT	f_t	R/S	
				<RESULTS>
2.2	SPECIAL CASE: PRESS		B	NO. OF ROWS ?
2.2.1	ENTER TOTAL NUMBER OF ROWS	k	R/S	ENTER:
2.2.2	FOR n = 1,2, ... k, ENTER			C<n> ?
2.2.2.1	CATCH	C_t	R/S	
				<RESULTS>
3.	DISPLAY OF RESULTS			
3.1	COEFFICIENT OF DETERMINATION [r^2]			R^2 : (x)
3.2	INTERCEPT [a]			a : (x)
3.3	SLOPE [b]			b : (x)
3.4	DEPENDING ON THE CASE SELECTED			
3.4.1	CATCHABILITY COEFFICIENT, [q], CASE A			Q : (x)
3.4.2	FISHING MORTALITY [F], CASE B			F : (x)
3.5	ESTIMATE OF UNFISHED STOCK SIZE [N_o]			N : (x)
4.	TO REVIEW RESULTS, PRESS		E	<RESULTS>
5.	FOR A NEW SET OF DATA, PRESS AND GO TO STEP 2.		f c	* FB 17 *

REGISTERS, STATUS, FLAGS

PROGR. NAME: FB 17 (Leslie's Equation)

STATUS : REG. (PROGR.): 57
SIZE (MIN.) : 016 SIZE (MAX.): -

FLAGS : 9, 10

ASSIGNMENTS:

A: GENERAL COMMANDS

B: SPECIAL COMMANDS

INITIALIZE : (f)c
REVIEW RESULTS : E
RECALL MENU : C

CHANGING EFFORT : A
CONSTANT EFFORT : B

REGISTERS :

SUB- PROGR.:	A	B	A	B
00 :	[u]	[u]	other results stored in X-register	
01 :	[u]	[u]		
02 :	[u]	[u]		
03 :	$\overline{r}^2$	$\overline{r}^2$		
04 :	a	a		
05 :	b	b		
06 :	-	-		
07 :	-	-		
08 :	[u]	[u]		
09 :	[u]	[u]		
10 :	[u]	[u]		
11 :	[u]	[u]		
12 :	[u]	[u]		
13 :	[u]	[u]		
14 :	[u]	[u]		
15 :	[u]	[u]		

Program Listing

(FB 17)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01*LBL "FB 17"		57 ARCL Y		113 SF 13		169 CF 21			
02*LBL c		58 "F" ?"		114 RCL 04		170 .END.			
03 CF 21		59 PROMPT		115 "P+2"					
04 BEEP		60 GTO 02		116 XEQ 10					
05 " * FB 17 *"		61*LBL 01		117 RCL 05					
06 AVIEW		62 1		118 "a "					
07 SREG 10		63*LBL 02		119 XEQ 10					
08 SF 27		64 RCL 01		120 RCL 06					
09 CLRG		65 X<>Y		121 "b "					
10 CF 09		66 /		122 XEQ 10					
11 CF 10		67 RCL 02		123 CHS					
12 PSE		68 S+		124 FS? 10					
13*LBL c		69 RCL 01		125 GTO 01					
14 "MENU :"		70 ST+ 02		126 "*0*"					
15 AVIEW		71 ISG 00		127 GTO 02					
16 PSE		72 GTO 00		128*LBL 01					
17 "CH. EFFORT : A"		73 RCL 14		129 CF 13					
18 AVIEW		74 RCL 10		130 "F "					
19 PSE		75 RCL 12		131*LBL 02					
20 "CST. EFFORT: B"		76 *		132 XEQ 10					
21 AVIEW		77 RCL 15		133 CF 13					
22 PSE		78 /		134 /					
23 "MENU : C"		79 -		135 "N "					
24 AVIEW		80 STO 06		136 XEQ 10					
25 PSE		81 X+2		137 STOP					
26 "INIT.: c"		82 RCL 13		138 GTO E					
27 AVIEW		83 RCL 12		139*LBL 10					
28 PSE		84 X+2		140 "F : "					
29 "REV. RES.: E"		85 RCL 15		141 FS? 55					
30 PROMPT		86 /		142 GTO 01					
31*LBL B		87 -		143 ARCL X					
32 SF 10		88 /		144 AVIEW					
33*LBL A		89 RCL 11		145 PSE					
34 "NO. OF ROWS ?"		90 RCL 10		146 PSE					
35 PROMPT		91 X+2		147 RTN					
36 "ENTER :"		92 RCL 15		148*LBL 01					
37 AVIEW		93 /		149 SF 21					
38 3		94 -		150 ACA					
39 10+X		95 ST/ 06		151 ACX					
40 /		96 /		152 PRBUF					
41 1		97 STO 04		153 CF 21					
42 +		98 RCL 12		154 RTN					
43 STO 00		99 RCL 06		155*LBL 11					
44 PSE		100 RCL 10		156 SF 21					
45 FIX 0		101 *		157 ADV					
46*LBL 00		102 -		158 ADV					
47 RCL 00		103 RCL 15		159 SF 12					
48 INT		104 /		160 "FB 17"					
49 "C <"		105 STO 05		161 ACA					
50 ARCL X		106*LBL E		162 PRBUF					
51 "F" ?"		107 FC? 55		163 "RESULTS"					
52 PROMPT		108 GTO 01		164 ACA					
53 STO 01		109 FC? 09		165 PRBUF					
54 FS? 10		110 XEQ 11		166 CF 12					
55 GTO 01		111*LBL 01		167 ADV					
56 "*F= <"		112 FIX 3		168 SF 09					

EXAMPLE 3.17

(See also p. 99 in manual)

Data from Appendix I,
Tab. 6.2 and 6.3

**FB 17
RESULTS**

r_{t2} : 0.881
a : 5.392
b : -0.349
q : 0.349
N : 15.460
r_{t2} : 0.001
a : 4.123
b : 0.007
F : -0.007
N : -553.440

**FB 17
RESULTS**

r_{t2} : 0.978
a : 7.864
b : -0.314
q : 0.314
N : 25.049

FB 18: PROGRAM DESCRIPTION FB 18

VPA and Cohort Analysis

Program FB 18 calculates the value of F which satisfies the equation

$$\frac{N_{i+1}}{C_i} = \frac{(F_i + M) \exp \{-(F_i + M)\}}{F_i (1 - \exp \{-(F_i + M)\})} \quad \dots 1)$$

where C_i is the catch at age i , N_i and N_{i+1} being the population sizes at the beginning and the end of the time period during which the catch C_i was taken (Gulland 1965, Cushing 1983).

The computation proceeds backward, starting from a "terminal population" (N_t) which is estimated from

$$N_t = \frac{C_t \cdot (F_t + M)}{F_t (1 - \exp \{-(F_t + M)\})} \quad \dots 2)$$

where F_t is the (assumed) terminal fishing mortality and C_t the terminal catch.

Equation (1) is solved iteratively, using the Newton method, and the derivative of Pope's equation (1972) for cohort analysis to obtain approximations of the slope of (1).

An alternative to VPA is to estimate N_i using Pope's approximation ("cohort analysis")

$$N_i = (N_{i+1} e^{M/2} + C_i) e^{M/2} \quad \dots 3)$$

with F_i being estimated from N_i , N_{i+1} and M (Pope 1972).

Operating Limits and Warnings

Estimation of the N_i and F_i -values must proceed backwards, i.e., starting with N_t as first estimate of N_{i+1} . The values of N_i and F_i will converge toward their true values, even when F_t was a wild guess. The values of N_i and F_i immediately preceding N_t and F_t are to be treated with suspicion, however. They may be improved by using as F_t one of the F_i -values obtained from a preliminary VPA.

When using cohort analysis, M -values should not be higher than 0.3 per time unit. The reliability of results obtained by VPA and cohort analysis increases with increasing values of F . Unless M is known with a high degree of precision, these methods should not be used in lightly exploited stocks.

FB 18: VPA AND COHORT ANALYSIS

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM			* FB 18 *
1.	ENTER TOTAL NUMBER OF ROWS	k	R/S	NO. OF ROWS ? TERMIN. POP.: ENTER:
2.	FOR TERMINAL POPULATION, ENTER:			M ?
2.1	NATURAL MORTALITY	M	R/S	F<T> ?
2.2	TERMINAL F	F _t	R/S	C<T> ?
2.3	TERMINAL CATCH	C _t	R/S	
2.4	RESULT: TERMINAL POPULATION [N _t]			N<T>: (x)
3.	DISPLAY OF MENU			MENU: VPA: A COHORT AN.: B MENU: C INIT.: c REV. RES.: E
4.	SELECT:			
4.1	VPA		A	TOL: .001
4.1.1	SUGGESTED VALUE FOR "TOL" = 0.001			CHANGE ? YES: 1, NO: 0
4.1.1.1	IF A DIFFERENT VALUE FOR TOL IS TO BE ENTERED, PRESS	1	R/S	NEW TOL?
	AND ENTER NEW TOL VALUE	TOL	R/S	ENTER CATCH:
4.1.1.2	NO CHANGE OF TOL VALUE, PRESS	0	R/S	ENTER CATCH:
4.2	COHORT ANALYSIS		B	ENTER CATCH: C<k-1> ?
5.	ENTER ALL CATCHES, STARTING WITH THE NEXT TO LAST CATCH AND PROCEED BACKWARDS UNTIL THE FIRST CATCH HAS BEEN ENTERED (i=k-1...1)	C _i	R/S	<RESULTS>

FB 18: VPA AND COHORT ANALYSIS

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
6.	DISPLAY OF RESULTS ^(a)			
6.1	POPULATION [N.]			N: (x)
6.2	FISHING MORTALITY [F_1]			F: (x)
7.	OPTIONS			
7.1	FOR REVIEWING RESULTS, PRESS		E	<RESULTS>
7.2	TO REVIEW MENU, PRESS		C	<MENU>
7.3	TO APPLY THE ALTERNATIVE METHOD TO THE <u>SAME SET OF DATA</u> GO TO STEP 4.			
7.4	FOR A NEW <u>SET OF DATA</u> , PRESS AND GO TO STEP 1.		f·c	* FB 18 *

a) NOTE: IF NO PRINTER IS CONNECTED, PROGRAM STOPS AFTER DISPLAYING "F: (x)" TO ALLOW WRITING DOWN RESULTS. TO CONTINUE, PRESS R/S.

REGISTERS, STATUS, FLAGS

PROGR. NAME: FB 18 (VPA and Cohort Analysis)

STATUS : REG. (PROGR.): 93
SIZE (MIN.) : 013 SIZE (MAX.): -

FLAGS : 6 - 8, 10

ASSIGNMENTS:

A: GENERAL COMMANDS

B: SPECIAL COMMANDS

INITIALIZE : (f)c
REVIEW RESULTS : E
RECALL MENU : C

VPA : A
COHORT ANALYSIS : B

REGISTERS :

SUB- PROGR.:	A	B
00 :	[u]	[u]
01 :	M	M
02 :	F	F
03 :	Z	Z
04 :	N	N
05 :	[u]	[u]
06 :	C	C
07 :	[u]	[u]
08 :	[u]	[u]
09 :	[u]	[u]
10 :	[u]	[u]
11 :	[u]	[u]
12 :	[u]	[u]

Program Listing

(FB 18)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01	LBL "FB 18"	57	ETX	113	FIX 2	169	ENTER†	225	CHS
02	LBL C	58	STO 09	114	"M . "	170	RCL 01	226	RCL 01
03	CF 21	59	LBL C	115	ARCL 01	171	+	227	-
04	BEEP	60	"MENU : "	116	ACA	172	STO 03	228	STO 02
05	" * FB 18 *"	61	AVIEW	117	PRBUF	173	/	229	LBL e
06	AVIEW	62	PSE	118	CF 21	174	*	230	FS? 55
07	SF 27	63	"VPA : A"	119	LBL 01	175	RCL 07	231	GTO 01
08	CLRG	64	AVIEW	120	"T"	176	*	232	LBL E
09	CF 07	65	PSE	121	ASTO 10	177	RCL 09	233	FS? 06
10	CF 08	66	"COHORT AN.: B"	122	"ENTER CATCH:"	178	X†2	234	SF 07
11	CF 10	67	AVIEW	123	AVIEW	179	RCL 11	235	FIX 0
12	PSE	68	PSE	124	FS? 55	180	*	236	"N . "
13	FS? 55	69	"MENU : C"	125	XEQ "Z"	181	RCL 06	237	ARCL 07
14	XEQ 11	70	AVIEW	126	RCL 00	182	*	238	AVIEW
15	"NO. OF ROWS ?"	71	PSE	127	STO 10	183	-	239	PSE
16	PROMPT	72	"INIT.: c"	128	PSE	184	STO 12	240	PSE
17	"TERMIN. POP.:"	73	AVIEW	129	GTO 01	185	X†2	241	RCL 02
18	AVIEW	74	PSE	130	LBL "K"	186	RCL 05	242	FIX 2
19	STO 00	75	"REV. RES.: E"	131	FS?C 07	187	X†Y?	243	RND
20	PSE	76	PROMPT	132	GTO 02	188	GTO 01	244	"F : "
21	PSE	77	GTO C	133	FS? 55	189	RCL 08	245	ARCL X
22	"ENTER :"	78	LBL B	134	XEQ "Z"	190	RCL 11	246	AVIEW
23	AVIEW	79	SF 10	135	LBL 01	191	*	247	FC? 07
24	PSE	80	"C. A."	136	DSE 10	192	RCL 12	248	STOP
25	"M ?"	81	GTO 01	137	LBL 02	193	X<Y	249	LBL 01
26	PROMPT	82	LBL A	138	FIX 0	194	/	250	SF 06
27	STO 01	83	FIX 3	139	"C <"	195	RCL 02	251	RCL 10
28	"F<T> ?"	84	.001	140	ARCL 10	196	X<Y	252	1
29	PROMPT	85	STO 05	141	"F> ?"	197	-	253	X*Y?
30	STO 02	86	"TOL : "	142	PROMPT	198	STO 02	254	GTO "K"
31	+	87	ARCL X	143	STO 06	199	GTO "L"	255	FS? 55
32	STO 03	88	AVIEW	144	CF 06	200	LBL 01	256	XEQ "Z"
33	"C<T> ?"	89	PSE	145	FS? 10	201	RCL 02	257	BEEP
34	PROMPT	90	PSE	146	GTO 05	202	RCL 01	258	GTO C
35	STO 06	91	"CHANGE ?"	147	RCL 07	203	+	259	LBL "Z"
36	*	92	AVIEW	148	RCL 09	204	STO 03	260	SF 21
37	RCL 02	93	PSE	149	*	205	ETX	261	FIX 0
38	1	94	"YES: 1, NO: 0"	150	RCL 06	206	RCL 07	262	ADV
39	RCL 03	95	PROMPT	151	RCL 01	207	*	263	6
40	CHS	96	X=0?	152	CHS	208	STO 07	264	"C"
41	ETX	97	GTO 02	153	ETX	209	GTO e	265	XEQ 01
42	-	98	"NEW TOL ?"	154	*	210	LBL 05	266	7
43	*	99	PROMPT	155	+	211	RCL 01	267	"N"
44	/	100	STO 05	156	STO 08	212	2	268	XEQ 01
45	STO 04	101	LBL 02	157	LBL "L"	213	/	269	2
46	STO 07	102	"V P A"	158	1	214	ETX	270	"F"
47	FIX 0	103	LBL 01	159	RCL 09	215	*	271	SF 08
48	"W<T> : "	104	FC? 55	160	X†2	216	RCL 07	272	XEQ 01
49	ARCL X	105	GTO 01	161	RCL 02	217	RCL 01	273	CF 21
50	AVIEW	106	SF 21	162	CHS	218	ETX	274	FIX 0
51	PSE	107	ADV	163	ETX	219	*	275	RTN
52	PSE	108	ADV	164	STO 11	220	+	276	LBL 01
53	RCL 01	109	ACA	165	*	221	X<Y 07	277	"F<"
54	2	110	PRBUF	166	-	222	RCL 07	278	ARCL 10
55	/	111	CF 12	167	RCL 02	223	/	279	"F> :"
56	CHS	112	ADV	168	ENTER†	224	LN	280	ACA

Program Listing

(FB 18 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
281	RCL IND X						
282	FS?C 08						
283	FIX 2						
284	RND						
285	ACX						
286	PRBUF						
287	RTN						
288	LBL 11						
289	SF 21						
290	ADV						
291	ADV						
292	SF 12						
293	"FB 18"						
294	ACA						
295	PRBUF						
296	CF 21						
297	.END.						

EXAMPLE 3.18

(See also p. 109 and 110 in manual)

Data from Appendix I,
Tab. 7.6

FB 18

C. A.

M : 0.20

C(T) : 110.

N(T) : 667.

F(T) : 0.20

C(20.) : 0.

N(20.) : 815.

F(20.) : 0.00

C(19.) : 1,160.

N(19.) : 2,278.

F(19.) : 0.83

C(18.) : 1,020.

N(18.) : 3,909.

F(18.) : 0.34

.

.

.

C(2.) : 120,060.

N(2.) : 1,514,092.

F(2.) : 0.09

C(1.) : 8,230.

N(1.) : 1,858,412.

F(1.) : 0.00

Data from Appendix I,
Tab. 7.5

FB 18

V P A

M : 0.20

C(T) : 17,538.

N(T) : 106,394.

F(T) : 0.20

C(16.) : 7,859.

N(16.) : 138,612.

F(16.) : 0.06

C(15.) : 5,225.

N(15.) : 175,063.

F(15.) : 0.03

C(14.) : 34,226.

N(14.) : 251,483.

F(14.) : 0.16

.

.

.

C(2.) : 139,836.

N(2.) : 11,761,034.

F(2.) : 0.01

C(1.) : 15,624.

N(1.) : 14,382,197.

F(1.) : 0.00

3.19: PROGRAM DESCRIPTION FB 19

Jones' Length Cohort Analysis

Pope's (1972) cohort analysis, generalized for any time interval Δt is

$$N_i = \left[N_{i+\Delta t} e^{M \Delta t/2} + C_{i-2} \right] e^{M \Delta t/2} \quad \dots 1)$$

substituting length for age (using the generalized VBGF) and rearranging gives

$$N_1 = [(N_2 X_L) + C_{1-2}] X_L \quad \dots 2)$$

where

$$X_L = \left[\frac{L_{\infty}^D - L_1^D}{L_{\infty}^D - L_2^D} \right]^{M/2KD} \quad \dots 3)$$

where N_1 is the number of fishes at length 1, while C_{1-2} is the catch of fish of length L_1 to L_2 . Having estimated a value of N for the largest fish, successive applications of equation (1) lead to estimates of N for the smaller fish. The rate of exploitation ($E = F/Z$) can be computed from

$$E = F/Z = \text{number caught/number dying} \quad \dots 4)$$

Z is then estimated from E via

$$Z = M/(1-E) \quad \dots 5)$$

and F via

$$F = Z - M \quad \dots 6)$$

The method is based on Jones (1974, 1981).

Operating Limits and Warnings

The limitations of length cohort analysis are discussed in detail in papers by Jones (1974, 1981) and must be considered whenever this method is applied to a set of catch data. The results of length-cohort analysis are sensitive to wide class intervals used for structuring the catch data; for this reason, it may be more appropriate to use length-structured VPA (program FB 20) whenever separate values of M and K are available.

Also note that using this method (as well as length-structured VPA, program FB 20) with a value of L_{∞} very close to $L_{\max}$ will cause a bias in the population estimates, while using a relatively large value of L_{∞} (and a correspondingly small value of K) reduces this bias.

FB 19: JONES' LENGTH COHORT ANALYSIS

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM			* FB 19 * : NO. OF ROWS ? ENTER CONST.:
1.	ENTER NUMBER OF INPUTS	k	R/S	
2.	ENTER CONSTANTS:			L<00> ?
2.1	$D^a)^{L_{\infty}}$	L_{∞}	R/S	D ?
2.2		D^{∞}	R/S	M ?
2.3	MORTALITY, CHOOSE:			
2.3.1	CASE 1: M IS KNOWN			
2.3.1.1	ENTER M	M	R/S	K ?
2.3.1.2	ENTER K	K	R/S	TERMIN. POP.: ENTER
2.3.2	CASE 2: M IS NOT KNOWN			
2.3.2.1	DON'T ENTER ANYTHING, PRESS		R/S	M/K*D?
2.3.2.2	ENTER A VALUE OF M/K*D	$\overline{M}/K*D$	R/S	TERMIN. POP.:
3.	FOR TERMINAL POP., ENTER			L<T> ?
3.1	UPPER LIMIT OF LARGEST LENGTH CLASS	L_1	R/S	dL ?
3.2	LENGTH CLASS INTERVAL	L	R/S	C<T> ?
3.3	TERMINAL CATCH	C_t	R/S	E<T> : 0.50
3.4	SUGGESTED TERMINAL EXPLOITATION RATE: $E_t = 0.50$			CHANGE ? YES: 1, NO: 0
3.4.1	IF YOU WANT TO CHANGE E_t , ENTER "1"	1	R/S	NEW E<T> ?
3.4.1.1	ENTER NEW E_t	E_t	R/S	<T. POP.: RESULTS>
3.4.2	IF YOU DON'T WANT TO CHANGE E_t , ENTER	0	R/S	<T. POP.: RESULTS>
4.	DISPLAY TERMIN. POPUL.			
4.1	ESTIMATE OF TERMINAL POP.			N<T>: (x)
4.2	IN CASE, M IS KNOWN (SEE 2.3.1)			
4.2.1	ESTIMATE OF TERMINAL TOTAL MORTALITY (Z_t)			Z<T>: (x)
4.2.2	ESTIMATE OF TERMINAL FISHING MORTALITY (F_t)			F<T>: (x)

a) NOTE: IN CASE OF SPECIAL VBGF, SIMPLY PRESS "R/S"; D IS THEN SET EQUAL TO 1

FB 19: JONES' LENGTH COHORT ANALYSIS

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
5.	ENTER ALL CATCHES STARTING WITH THE NEXT TO LAST CATCH AND PROCEEDING BACKWARDS UNTIL THE FIRST CATCH HAS BEEN ENTERED ($i=k-1 \dots 1$)	C_i	R/S	<RESULTS>
6.	DISPLAY OF RESULTS ^{a)}			
6.1	POPULATION SIZE $[N_i]$			N: (x)
6.2	EXPLOITATION RATE $[E_{i-i+1}]$			E: (x)
6.3	IN CASE, M IS KNOWN			
6.3.1	TOTAL MORTALITY $[Z_{i-i+1}]$			Z: (x)
6.3.2	FISHING MORTALITY $[F_{i-i+1}]$			F: (x)
7.	OPTION:			
7.1	RESULTS IN STEP 4 AND 6 CAN BE REVIEWED AT ANY PROGRAM STOP BY PRESSING		E	<RESULTS>
8.	FOR A NEW SET OF DATA, PRESS AND GO TO STEP 1.		f c	* FB 19 *

a) NOTE: IF NO PRINTER IS CONNECTED, THE PROGRAM STOPS AFTER DISPLAYING "E: ..." [OR "F: ..." RESPECTIVELY] TO ALLOW WRITING DOWN RESULTS; TO CONTINUE, SIMPLY PRESS "R/S".

REGISTERS, STATUS, FLAGS

PROGR. NAME: FB 19 (Jones' Length Cohort Analysis)

STATUS : REG. (PROGR.): 103
SIZE (MIN.) : 016 SIZE (MAX.): -

FLAGS : 6 - 8, 10

ASSIGNMENTS:

A: GENERAL COMMANDS

B: SPECIAL COMMANDS

INITIALIZE : (f)c

REVIEW RESULTS : E

REGISTERS :

SUB-
PROGR.: A

00 : [u]
01 : [u]
02 : [u]
03 : Z
04 : [u]
05 : N
06 : [u]
07 : [u]
08 : [u]
09 : [u]
10 : [u]
11 : [u]
12 : [u]
13 : [u]
14 : E
15 : F

Program Listing

(FB 19)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01	LBL "FB 19"	57	LBL 11	113	STO 11	169	PSE	225	FS? 10
02	LBL c	58	SF 21	114	-	170	GTO 01	226	GTO e
03	CF 21	59	ADV	115	STO 07	171	LBL "K"	227	1
04	BEEP	60	ADV	116	"C(T) ?"	172	FS? 07	228	X(Y)
05	" * FB 19 *"	61	SF 12	117	PROMPT	173	GTO 02	229	-
06	AVIEW	62	"FB 19"	118	STO 12	174	FS? 55	230	1/X
07	SF 27	63	GTO 01	119	FIX 2	175	XEQ "Z"	231	RCL 02
08	CLRG	64	LBL 12	120	.5	176	LBL 01	232	*
09	CF 07	65	SF 21	121	STO 14	177	DSE 13	233	STO 03
10	CF 06	66	ADV	122	"E"	178	LBL 02	234	RCL 02
11	CF 10	67	"CONSTANTS "	123	XEQ "X"	179	FIX 0	235	-
12	PSE	68	LBL 01	124	"CHANGE ?"	180	"C <"	236	STO 15
13	FS? 55	69	ACA	125	AVIEW	181	ARCL 13	237	LBL e
14	XEQ 11	70	PRBUF	126	PSE	182	"> ?"	238	FS? 55
15	"NO. OF ROWS ?"	71	CF 21	127	"YES: 1, NO: 0"	183	PROMPT	239	GTO 00
16	PROMPT	72	CF 12	128	PROMPT	184	STO 12	240	LBL E
17	STO 09	73	RTN	129	X=0?	185	CF 06	241	FS? 06
18	"ENTER CONST.:"	74	LBL 06	130	GTO 01	186	RCL 10	242	SF 07
19	AVIEW	75	FS? 55	131	"NEW E(T) ?"	187	RCL 04	243	FIX 0
20	FS? 55	76	"F "	132	PROMPT	188	YIX	244	TONE 6
21	XEQ 12	77	LBL 03	133	STO 14	189	ENTER+	245	RCL 05
22	PSE	78	FS? 55	134	LBL 01	190	ENTER+	246	"N"
23	"L(00)"	79	XEQ 04	135	RCL 12	191	RCL 07	247	XEQ "Y"
24	FIX 2	80	"< ?"	136	RCL 14	192	RCL 04	248	RCL 14
25	XEQ 03	81	PROMPT	137	/	193	YIX	249	FIX 2
26	STO 10	82	FS? 55	138	STO 05	194	-	250	RND
27	CF 22	83	XEQ 05	139	FIX 0	195	RCL Y	251	TONE 7
28	"D"	84	RTN	140	"N"	196	RCL 00	252	"E"
29	FS? 22	85	LBL 04	141	XEQ "X"	197	RCL 04	253	XEQ "Y"
30	GTO 01	86	SF 21	142	FS? 10	198	YIX	254	FS? 10
31	SF 22	87	ACA	143	GTO 01	199	-	255	GTO 02
32	1	88	CF 21	144	RCL 02	200	/	256	RCL 03
33	LBL 01	89	RTN	145	1	201	RCL 00	257	RND
34	XEQ 06	90	LBL 05	146	RCL 14	202	2	258	TONE 8
35	STO 04	91	SF 21	147	-	203	/	259	"Z"
36	CF 22	92	CLA	148	/	204	YIX	260	XEQ "Y"
37	"M"	93	"F :"	149	FIX 2	205	STO 06	261	RCL 15
38	XEQ 06	94	ACA	150	STO 03	206	RCL 05	262	RND
39	FC? 22	95	FS? 22	151	"Z"	207	STO 09	263	TONE 9
40	GTO 01	96	ACX	152	XEQ "X"	208	*	264	"F :"
41	STO 02	97	PRBUF	153	RCL 02	209	RCL 12	265	ARCL X
42	"K"	98	CF 21	154	-	210	+	266	AVIEW
43	FIX 3	99	RTN	155	STO 15	211	RCL 06	267	LBL 02
44	XEQ 06	100	LBL 10	156	"F"	212	*	268	FC? 07
45	STO 01	101	"TERMIN. POP.:"	157	XEQ "X"	213	STO 05	269	STOP
46	/	102	AVIEW	158	LBL 01	214	RCL 07	270	LBL 00
47	X(Y)	103	PSE	159	SF 06	215	STO 08	271	SF 06
48	/	104	PSE	160	RCL 02	216	RCL 11	272	RCL 13
49	STO 00	105	"ENTER :"	161	"T"	217	-	273	1
50	GTO 10	106	AVIEW	162	ASTO 13	218	STO 07	274	X*Y?
51	LBL 01	107	PSE	163	"ENTER CATCH:"	219	RCL 12	275	GTO "K"
52	SF 10	108	"L(T) ?"	164	AVIEW	220	RCL 05	276	FS? 55
53	"M/K*D"	109	PROMPT	165	FS? 55	221	RCL 09	277	XEQ "Z"
54	XEQ 03	110	STO 08	166	XEQ "Z"	222	-	278	PSE
55	STO 00	111	"dL ?"	167	RCL 09	223	/	279	" * END *"
56	GTO 10	112	PROMPT	168	STO 13	224	STO 14	280	PROMPT

Program Listing

(FB 19 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
281	GTO E								
282	*LBL "Z"								
283	SF 21								
284	ADV								
285	12								
286	"C"								
287	XEQ 01								
288	5								
289	"N"								
290	XEQ 01								
291	14								
292	"E"								
293	SF 08								
294	XEQ 01								
295	FS? 10								
296	GTO 02								
297	3								
298	"Z"								
299	SF 08								
300	XEQ 01								
301	15								
302	"F"								
303	SF 08								
304	XEQ 01								
305	*LBL 02								
306	CF 21								
307	FIX 0								
308	RTN								
309	*LBL 01								
310	FIX 0								
311	"I<"								
312	ARCL 13								
313	"I>" :								
314	ACA								
315	RCL IND X								
316	FS?C 08								
317	FIX 2								
318	RND								
319	ACX								
320	PRBUF								
321	RTN								
322	*LBL "X"								
323	"I<T>"								
324	XEQ "Y"								
325	PSE								
326	RTN								
327	*LBL "Y"								
328	"I : "								
329	ARCL X								
330	RVIEW								
331	PSE								
332	PSE								
333	.END.								

EXAMPLE 3.19

(See also p. 112 in manual)

Data from Appendix I,
Tab. 7.7

Data from Appendix I,
Tab. 7.7

FB 19

CONSTANTS :

L<00> : 130.00

D : 1.00

M : 0.28

K : 0.100

C<T> : 46.

N<T> : 92.

E<T> : 0.50

Z<T> : 0.56

F<T> : 0.28

C<13.> : 16.

N<13.> : 149.

E<13.> : 0.28

Z<13.> : 0.39

F<13.> : 0.11

C<12.> : 96.

N<12.> : 314.

E<12.> : 0.58

Z<12.> : 0.67

F<12.> : 0.39

C<11.> : 181.

N<11.> : 621.

E<11.> : 0.59

Z<11.> : 0.68

F<11.> : 0.40

C<2.> : 14,463.

N<2.> : 84,393.

E<2.> : 0.58

Z<2.> : 0.67

F<2.> : 0.39

C<1.> : 1,823.

N<1.> : 98,919.

E<1.> : 0.13

Z<1.> : 0.32

F<1.> : 0.04

FB 19

CONSTANTS :

L<00> : 130.00

D : 1.00

M :

M/K*D : 2.80

C<T> : 46.

N<T> : 92.

E<T> : 0.50

C<13.> : 16.

N<13.> : 149.

E<13.> : 0.28

C<12.> : 96.

N<12.> : 314.

E<12.> : 0.58

C<11.> : 181.

N<11.> : 621.

E<11.> : 0.59

C<2.> : 14,463.

N<2.> : 84,393.

E<2.> : 0.58

C<1.> : 1,823.

N<1.> : 98,919.

E<1.> : 0.13

3.20: PROGRAM DESCRIPTION FB 20

Length-structured VPA

In analogy to Jones' (1974) conversion of Pope's (1972) cohort analysis to a method suitable for the analysis of catch-at-length data, Gulland's (1965) Virtual Population Analysis (VPA) can be used to estimate fishing mortality and population sizes from catch-at-length data. Gulland's VPA has the form

$$\frac{N_{i+1}}{C_i} = \frac{(F_i + M) \exp \{-(F_i + M)\}}{F_i (1 - \exp \{-(F_i + M)\})} \quad \dots 1)$$

Generalized for any time interval Δt between ages 1 and 2, this becomes

$$\frac{N_{i+\Delta t}}{C_{1-2}} = \frac{(F_{1-2} + M) \Delta t \exp \{-(F_{1-2} + M) \Delta t\}}{(F_{1-2} \Delta t) (1 - \exp \{-(F_{1-2} + M) \Delta t\})} \quad \dots 2)$$

where N_1 is the number of age 1 and C_{1-2} and F_{1-2} are the catch and fishing mortality, respectively, pertaining to fishes ranging from age 1 to age 2.

Converting length to age, in terms of the generalized VBGF gives

$$t = \frac{\ln \left(\frac{L_{\infty}^D - L_1^D}{L_{\infty}^D - L_2^D} \right)}{KD} \quad \dots 3)$$

where L_1 and L_2 are the lengths pertaining to ages 1 and 2, respectively.

Operating Limits and Warnings

The properties of the method presented here are essentially the same as for VPA as far as convergence towards true fishing mortality is concerned, and the same as for Jones' length-cohort analysis as far as sensitivity to L_{∞} and K is concerned. The method, however, is insensitive to the effects of length class intervals that are very large, something which is not the case with Jones' length cohort analysis (see manual for details).

FB 20: LENGTH-STRUCTURED VPA

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM			* FB 20 *
1.	DISPLAY OF MENU			MENU
1.1	LENGTH-STRUCTURED VPA			L-STR. VPA : A
1.2	LENGTH-FREQ. CONVERSION TO CATCH-AT-LENGTH DATA			L-FR. CONV.: B
1.3	MENU			MENU : C
1.4	INITIALIZE			INIT. : c
1.5	REVIEW RESULTS			REV. RES. : e
2.	SELECT METHOD:			
2.1	<u>LENGTH-STRUCTURED VPA</u>		A	ENTER CONST.:
2.1.1	<u>ENTER CONSTANTS:</u>			L<00> ?
2.1.1.1	ASYMPTOTIC LENGTH	L	R/S	K ?
2.1.1.2	K _a)	K [∞]	R/S	D ?
2.1.1.3	D	D	R/S	M ?
2.1.1.4	NATURAL MORTALITY	M	R/S	TOL: 0.001
2.1.1.5	SUGGESTED TOLERATED ERROR: 0.001			CHANGE ?
2.1.1.6	OPTION:			YES: 1, NO: 0
2.1.1.6.1	IF YOU WANT TO CHANGE TOL, ENTER	1	R/S	NEW TOL ?
	ENTER NEW TOL	TOL	R/S	NO. OF ROWS ?
2.1.1.6.2	IF YOU DON'T WANT TO CHANGE TOL, ENTER	0	R/S	NO. OF ROWS ?
2.2	ENTER NUMBER OF ROWS	k	R/S	TERMIN. POP.: ENTER: L<T> ?
2.3	FOR TERMINAL POPULATION, ENTER			
2.3.1	UPPER LIMIT OF LARGEST LENGTH CLASS	L _t	R/S	dL ?
2.3.2	LENGTH CLASS INTERVAL	ΔL	R/S	F<T> ?
2.3.3	TERMINAL FISHING MORTALITY	F _t	R/S	C<T> ?
2.3.4	TERMINAL CATCH (RESULT: ESTIM. OF TERMINAL POPULATION)	C _t	R/S	N<T>: (x)

a) PRESS R/S TO SET D=1.

FB 20: LENGTH-STRUCTURED VPA

USER INSTRUCTIONS (cont.)

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
2.4	ENTER ALL CATCHES, STARTING WITH THE NEXT TO LAST CATCH AND PROCEEDING BACKWARDS UNTIL THE FIRST CATCH HAS BEEN ENTERED $[i=k-1 \dots 1]$	C_i	R/S	<RESULTS>
2.5	DISPLAY OF RESULTS ^{a)}			N:
2.5.1	POPULATION SIZE			F:
2.5.2	FISHING MORTALITY			
2.6	OPTION:			
2.6.1	NEW SET OF DATA, SAME CONSTANTS (CONTINUE AT STEP 2.2)		A	NO. OF ROWS ?
2.6.2	NEW SET OF DATA, DIFFERENT CONSTANTS (CONTINUE AT STEP 2.)		f c	<MENU>
2.6.3	DIFFERENT METHOD (CONTINUE AT 3.)		f c	<MENU>
3.	<u>CONVERSION OF LENGTH-FREQUENCY DATA TO CATCH-AT-LENGTH DATA</u>		B	L-WT. REL.SHIP ENTER CONST.:
3.1	ENTER PARAMETERS OF LENGTH-WEIGHT RELATIONSHIP [FORM: $W=aL^b$]			a ? b ?
3.1.1	a	a	R/S	b ?
3.1.2	b	b	R/S	L-FR. CONV.:
3.2	FOR LENGTH-FREQUENCY CONVERSION, ENTER:			NO. OF ROWS ?
3.2.1	NO. OF ROWS	k	R/S	L<MIN> ?
3.2.2	LOWER LIMIT OF SMALLEST LENGTH CLASS CONSIDERED	L_{min}	R/S	dL ?
3.2.3	LENGTH CLASS INTERVAL	ΔL	R/S	ENTER FREQ.:
3.3	ENTER ALL FREQUENCIES, INCLUDING ZERO FREQUENCIES: START AT L_{min} AND PROCEED UNTIL YOU REACH THE LARGEST LENGTH CLASS CONSIDERED ($i=L_{min} \dots L_{min+k\Delta L}$)	N_i	R/S	N<i> ? M.WT.<i>: (x)

a) NOTE: IF NO PRINTER IS CONNECTED, THE PROGRAM STOPS AFTER DISPLAYING "F: (x)" TO ALLOW WRITING DOWN RESULTS; TO PROCEED, PRESS "R/S".

FB 20: LENGTH-STRUCTURED VPA

USER INSTRUCTIONS (cont.)

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
	[AFTER EACH ENTRY, PROGRAM STOPS SHORTLY TO DISPLAY THE WEIGHT OF THE FISH IN THE CORRESPONDING LENGTH CLASS, BASED ON THE LENGTH-WEIGHT RELATIONSHIP ENTERED]			
3.4	RESULTS			
3.4.1	TOTAL WEIGHT OF SAMPLE			T. WT.<S>: (x)
3.4.2	MEAN WEIGHT OF THE FISH IN SAMPLE			M. WT.<A>: (x)
4.	OPTION:			
4.1	NEW SET OF DATA, SAME L-W REL. (CONTINUE AT STEP 3.2.1)		B	NO. OF ROWS ?
4.2	NEW SET OF DATA, DIFFERENT L-W REL. (CONTINUE AT STEP 3.)		f c	<MENU>
4.3	DIFFERENT METHOD (CONTINUE AT STEP 2.)		f c	<MENU>

REGISTERS, STATUS, FLAGS

PROGR. NAME: FB 20 (Length-Structured VPA)

STATUS : REG. (PROGR.): 168
SIZE (MIN.) : 017 SIZE (MAX.): -

FLAGS : 5 - 10

ASSIGNMENTS:

A: GENERAL COMMANDS

B: SPECIAL COMMANDS

INITIALIZE : (f)c
REVIEW RESULTS : E
RECALL MENU : C

LENGTH-STRUCTURED VPA : A
LENGTH-FREQUENCY CONV.: B

REGISTERS :

SUB- PROGR.:	A	B
00 :	[u]	[u]
01 :	[u]	[u]
02 :	[u]	T.WT.<S>
03 :	-	M.WT.<A>
04 :	[u]	[u]
05 :	[u]	[u]
06 :	N	[u]
07 :	C	[u]
08 :	[u]	[u]
09 :	F	-
10 :	[u]	M.WT.<L.CL>
11 :	[u]	[u]
12 :	[u]	-
13 :	[u]	-
14 :	[u]	-
15 :	[u]	-
16 :	[u]	[u]

Program Listing

(FB 20)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01	LBL "FB 20"	57	ADV	113	STO 10	169	AVIEW	225	AVIEW
02	LBL C	58	ACA	114	RCL 08	170	XEQ 01	226	PSE
03	CF 21	59	PRBUF	115	+	171	PSE	227	PSE
04	BEEP	60	CF 21	116	STO 06	172	PSE	228	"CHANGE ?"
05	" * FB 20 *"	61	LBL 01	117	RCL 05	173	RCL 03	229	AVIEW
06	AVIEW	62	PSE	118	YTX	174	FIX 2	230	PSE
07	SF 27	63	XEQ 10	119	RCL 04	175	/	231	"YES: 1, NO: 0"
08	CLRG	64	FIX 2	120	*	176	"M.WT.<A> : "	232	PROMPT
09	CF 05	65	"a "	121	STO 01	177	ARCL X	233	X=0?
10	CF 07	66	XEQ 03	122	RCL 00	178	AVIEW	234	GTO 02
11	CF 08	67	STO 04	123	+	179	XEQ 01	235	"NEW TOL ?"
12	CF 10	68	"b*"	124	2	180	STOP	236	PROMPT
13	PSE	69	XEQ 03	125	/	181	GTO C	237	STO 00
14	FS? 55	70	STO 05	126	STO 07	182	LBL 01	238	LBL 02
15	XEQ "P"	71	LBL 02	127	*	183	FC? 55	239	FC? 55
16	LBL C	72	"L.-FR. CONV."	128	ST+ 02	184	RTN	240	GTO 02
17	"MENU : "	73	AVIEW	129	RCL 01	185	FS? 07	241	RCL 00
18	AVIEW	74	FS? 55	130	STO 00	186	RTN	242	FIX 3
19	PSE	75	XEQ "P"	131	LBL "R"	187	SF 21	243	"TOL "
20	"L.-STR. VPA : A"	76	SF 21	132	FIX 0	188	ACA	244	XEQ 04
21	AVIEW	77	ADV	133	RCL 10	189	PRBUF	245	XEQ 05
22	PSE	78	CF 21	134	"M.WT.<"	190	CF 21	246	GTO 02
23	PSE	79	PSE	135	ARCL X	191	RTN	247	LBL 10
24	"L.-FR. CONV.: B"	80	SF 05	136	"I> : "	192	LBL A	248	"ENTER CONST. "
25	AVIEW	81	XEQ "U"	137	FIX 2	193	ADV	249	AVIEW
26	PSE	82	"L<MIN> ?"	138	FS? 06	194	ADV	250	FS? 55
27	PSE	83	PROMPT	139	GTO 01	195	"LENGTH VPA"	251	XEQ 12
28	"MENU : C"	84	STO 06	140	FS? 55	196	FS? 55	252	PSE
29	AVIEW	85	"dL"	141	XEQ 04	197	XEQ "P"	253	RTN
30	PSE	86	PROMPT	142	LBL 01	198	FS? 05	254	LBL 12
31	"INIT.: C"	87	STO 08	143	RCL 07	199	GTO 02	255	SF 21
32	AVIEW	88	RCL 06	144	FC? 55	200	XEQ 10	256	ADV
33	PSE	89	RCL 05	145	GTO 01	201	"L<00>"	257	"CONSTANTS :"
34	"REV. RES.: E"	90	YTX	146	FS? 06	202	FIX 2	258	ACA
35	PROMPT	91	RCL 04	147	GTO 01	203	XEQ 03	259	PRBUF
36	GTO C	92	*	148	SF 21	204	STO 10	260	CF 21
37	LBL "0"	93	STO 00	149	ACX	205	"K"	261	RTN
38	FC? 09	94	RCL 11	150	PRBUF	206	FIX 3	262	LBL 06
39	SF 07	95	3	151	CF 21	207	XEQ 06	263	FS? 55
40	SF 06	96	10TX	152	GTO 02	208	STO 12	264	"I> "
41	GTO "R"	97	/	153	LBL 01	209	CF 22	265	LBL 03
42	LBL B	98	1	154	ARCL X	210	"D"	266	FS? 55
43	CF 06	99	+	155	AVIEW	211	FC? 22	267	XEQ 04
44	CF 07	100	STO 16	156	PSE	212	1	268	"I> ?"
45	SF 10	101	SF 09	157	LBL 02	213	FIX 2	269	PROMPT
46	0	102	"ENTER FREQU.:"	158	FS? 07	214	XEQ 06	270	FS? 55
47	STO 02	103	AVIEW	159	GTO 01	215	STO 13	271	XEQ 05
48	STO 03	104	PSE	160	FC? 06	216	"M"	272	RTN
49	FS? 05	105	LBL "N"	161	ISG 16	217	XEQ 06	273	LBL 04
50	GTO 02	106	FIX 0	162	GTO "N"	218	STO 02	274	SF 21
51	"L.-WT. REL.SHIP"	107	"NK"	163	CF 09	219	FIX 3	275	ACA
52	AVIEW	108	ARCL 06	164	LBL 01	220	1 E-3	276	CF 21
53	FC? 55	109	"I> ?"	165	RCL 02	221	STO 00	277	RTN
54	GTO 01	110	PROMPT	166	FIX 0	222	TONE 7	278	LBL 05
55	SF 21	111	ST+ 03	167	"T.WT.<S> : "	223	"TOL : "	279	SF 21
56	ADV	112	RCL 06	168	ARCL X	224	ARCL X	280	CLA

Program Listing

(FB 20 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
281	"F :"	337	XEQ "Z"	393	CHS	449	FS? 10	505	ACX
282	ACA	338	*LBL 01	394	E1X	450	GTO "0"	506	PRBUF
283	ACX	339	DSE 16	395	STO 05	451	FS? 06	507	RTN
284	PRBUF	340	*LBL 02	396	RCL 04	452	SF 07	508	*LBL "P"
285	CF 21	341	FIX 0	397	X12	453	FIX 0	509	SF 21
286	RTN	342	"C <"	398	*	454	TONE 7	510	ADV
287	*LBL 02	343	ARCL 16	399	-	455	"N : "	511	ADV
288	SF 05	344	"F> ?"	400	RCL 09	456	ARCL 06	512	SF 12
289	XEQ "U"	345	PROMPT	401	RCL 02	457	AVIEW	513	ACA
290	"TERMIN. POP.:"	346	STO 07	402	RCL 09	458	PSE	514	PRBUF
291	AVIEW	347	CF 06	403	+	459	PSE	515	CF 21
292	PSE	348	RCL 10	404	/	460	RCL 09	516	CF 12
293	PSE	349	RCL 13	405	*	461	FIX 2	517	RTN
294	"ENTER :"	350	Y1X	406	RCL 06	462	RND	518	*LBL "U"
295	AVIEW	351	ENTER+	407	*	463	"F : "	519	"NO. OF ROWS ?"
296	PSE	352	ENTER+	408	RCL 04	464	ARCL X	520	PROMPT
297	"L<T> ?"	353	RCL 15	409	X12	465	AVIEW	521	STO 11
298	PROMPT	354	RCL 13	410	RCL 05	466	PSE	522	.END.
299	STO 15	355	Y1X	411	*	467	FC? 07		
300	"dL ?"	356	-	412	RCL 07	468	STOP		
301	PROMPT	357	RCL Y	413	*	469	*LBL 01		
302	STO 14	358	RCL 15	414	-	470	SF 06		
303	"F<T> ?"	359	RCL 14	415	STO 08	471	RCL 16		
304	PROMPT	360	-	416	X+2	472	1		
305	STO 09	361	STO 15	417	RCL 00	473	X*Y?		
306	"C<T> ?"	362	RCL 13	418	X>Y?	474	GTO "K"		
307	PROMPT	363	Y1X	419	GTO 01	475	FS? 55		
308	STO 07	364	-	420	RCL 09	476	XEQ "Z"		
309	X<Y	365	X<Y	421	RCL 00	477	BEEP		
310	RCL 02	366	/	422	RCL 01	478	GTO C		
311	+	367	LN	423	RCL 05	479	*LBL "Z"		
312	RCL 09	368	RCL 12	424	*	480	SF 21		
313	/	369	RCL 13	425	/	481	FIX 0		
314	*	370	*	426	-	482	ADV		
315	STO 06	371	/	427	STO 09	483	?		
316	FIX 0	372	STO 11	428	GTO "L"	484	"C"		
317	"N<T> : "	373	ST* 09	429	*LBL 01	485	XEQ 01		
318	ARCL X	374	ST* 02	430	RCL 09	486	6		
319	AVIEW	375	RCL 02	431	RCL 11	487	"N"		
320	PSE	376	2	432	/	488	XEQ 01		
321	PSE	377	/	433	STO 09	489	9		
322	SF 06	378	CHS	434	RCL 02	490	"F"		
323	"I"	379	E1X	435	RCL 11	491	SF 08		
324	ASTO 16	380	STO 04	436	/	492	XEQ 01		
325	"ENTER CATCH :"	381	RCL 06	437	STO 02	493	CF 21		
326	AVIEW	382	*	438	+	494	FIX 0		
327	FS? 55	383	RCL 07	439	RCL 11	495	RTN		
328	XEQ "Z"	384	RCL 02	440	*	496	*LBL 01		
329	RCL 11	385	CHS	441	E1X	497	"F<"		
330	STO 16	386	E1X	442	RCL 06	498	ARCL 16		
331	PSE	387	*	443	*	499	"F> :"		
332	GTO 01	388	+	444	STO 06	500	ACA		
333	*LBL "K"	389	STO 01	445	*LBL e	501	RCL IND X		
334	FS?C 07	390	*LBL "L"	446	FS? 55	502	FS?C 08		
335	GTO 02	391	1	447	GTO 01	503	FIX 2		
336	FS? 55	392	RCL 09	448	*LBL E	504	RND		

EXAMPLE 3.20

(See also p. 113 in manual)

Data from Appendix I,
Tab. 5.8

Data from Appendix I,
Tab. 7.7

* FB 20 *

* FB 20 *

L.-WT. REL.SHIP

LENGTH VPA

CONSTANTS :

a : 0.01

b* : 3.00

CONSTANTS :

L<00> : 130.00

K : 0.100

D : 1.00

M : 0.28

TOL : 0.001

L.-FR. CONV.

M.WT.<4.> : 1.40

M.WT.<6.> : 3.64

M.WT.<8.> : 7.56

M.WT.<10.> : 13.64

M.WT.<12.> : 22.36

T.WT.<9> : 2.530.

M.WT.<A> : 7.23

C<T> : 46.

N<T> : 92.

F<T> : 0.28

C<13.> : 16.

N<13.> : 148.

F<13.> : 0.11

C<12.> : 96.

N<12.> : 312.

F<12.> : 0.40

C<11.> : 181.

N<11.> : 616.

F<11.> : 0.41

C<2.> : 14.463.

N<2.> : 83.801.

F<2.> : 0.39

C<1.> : 1.823.

N<1.> : 98.238.

F<1.> : 0.04

3.21: PROGRAM DESCRIPTION FB 21

Yield-per-Recruit

Program FB 21 estimates yield-per-recruit, given growth and related parameters from any of the three equations

$$Y/R_r = F \cdot e^{-Mr_2} \cdot W_{\infty} \left[\frac{1-e^{-Zr_3}}{Z} - \frac{3e^{-Kr_1}(1-e^{-(Z+K)r_3})}{Z+K} + \frac{3e^{-2Kr_1}(1-e^{-(Z+2K)r_3})}{Z+2K} - \frac{e^{-3Kr_1}(1-e^{-(2+3K)r_3})}{Z+3K} \right] \quad \dots 1)$$

or

$$Y/R_r = F \cdot e^{-Mr_2} \cdot W_{\infty} \left[\frac{1}{Z} - \frac{3e^{-Kr_1}}{Z+K} + \frac{3e^{-2Kr_1}}{Z+2K} - \frac{e^{-3Kr_2}}{Z+3K} \right] \quad \dots 2)$$

where $Z = F + M$, $r_1 = t_c - t_o$, $r_2 = t_c - t_r$ and $r_3 = t_{\max} - t_c$

or

$$Y'/R_r = E(1-c)^{M/K} \left[1 - \frac{3(1-c)}{1 + \frac{K(1-E)}{M}} + \frac{3(1-c)^2}{1 + \frac{2K(1-E)}{M}} - \frac{(1-c)^3}{1 + \frac{3K(1-E)}{M}} \right] \quad \dots 3)$$

proposed by Beverton and Holt (1957), Jones (1957) and Beverton and Holt (1964) respectively. An option is also given to compute the slope of yield-per-recruit on F , as needed to estimate $F_{0.1}$. The equation used here (the partial derivative of equation 2) stems from P. Sparre (pers. comm.) and has the form:

$$\frac{(Y/R)}{F} = W_{\infty} \exp(-M(t_c - t_r)) \left[\frac{M}{Z^2} - 3S \frac{M+K}{(Z+K)^2} + 3S^2 \frac{M+2K}{(Z+2K)^2} - S^3 \frac{M+3K}{(Z+3K)^2} \right] \quad \dots 4)$$

where $S = \exp(-K(t_c - t_o))$.

Program FB 21 can also be used to estimate biomass per recruit (B/R_r) as a function of F . To do so, compute Y/R_r based on equation (1) or (2), then divide Y/R_r value by F .

Equations for computation of relative biomass per recruit (B/R_r), based on equation (3), and for computation of $E_{0.1}$ (a quantity analogous to $F_{0.1}$) are available from D. Pauly (manuscript).

Note that the relationship between Y/R_r and Y'/R_r (i.e. between absolute and relative yield per recruit is given by

$$Y/R_r = (Y'/R_r) \cdot W_{\infty} \cdot (\exp -(M(t_r - t_0))). \quad \dots 5)$$

Operating Limits and Warnings

These equations must be used only in conjunction with the special VBGF (when $D = 1$) and when weight growth is isometric. Equation (4) can be used only in conjunction with equation (2). Estimation of B/R_r using the procedure outlined above will not work for $F=0$; use a very low value of F (e.g. $F=0.01$) instead.

FB 21: YIELD-PER-RECRUIT

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM			* FB 21 *
1.	DISPLAY OF MENU			MENU
1.1	SIMPLIFIED VERSION (CASE I) ^{a)}			SIMPLIF. V.: H
1.2	ORIGINAL VERSION (CASE II) ^{b)}			ORIGIN. V. : I
1.3	JONES' VERSION (CASE III) ^{c)}			JONES V. : J
1.4	SLOPE VALUES FOR Y/R CURVE			Y/R SLOPE : F
1.5	{			MENU : C
1.6	{ SEE GENERAL INSTRUCTIONS			INIT. : c
1.7	{			REV. RES. : E
2.	SELECT CASE I, II, III		H/I/J	ENTER CONST.:
3.	<u>INPUT OF CONSTANTS:</u>			
3.1	FOR CASE I: ENTER			M/K ?
3.1.1	M/K	M/K	R/S	c ?
3.1.2	c [=L / L _∞]	c	R/S	Y/R-ESTIM.:
3.2	FOR CASE II & III: ENTER			W<00> ?
3.2.1	ASYMPTOTIC WEIGHT (IN G)	W	R/S	K ?
3.2.2	K (ANNUAL BASIS)	K _∞	R/S	M ?
3.2.3	NATURAL MORTALITY	M	R/S	T<MAX>?
3.2.4	LONGEVITY OF THE FISH (THIS STEP IS OMITTED IN JONES' VERSION)	t _{max}	R/S	T<0> ?
3.2.5	AGE AT LENGTH ZERO	t ₀	R/S	T<c> ?
3.2.6	MEAN AGE AT FIRST CAPTURE	t _c	R/S	T<r> ?
3.2.7	AGE AT RECRUITMENT	t _r	R/S	Y/R-ESTIM.:
4.	<u>COMPUTATION OF YIELD/RECRUIT</u>			Y/R-ESTIM.:
4.1	FOR CASE I: ENTER			ENTER:
4.1.1	EXPLOITATION RATE E(=Z/K)	E	R/S	E ?
4.1.2	PROMPTS/RESULTS: RELATIVE Y/R FOR AGE t			Y*<R>: (x)
4.2	FOR CASE II, III: ENTER			NEXT E ?
4.2.1	FISHING MORTALITY	F	R/S	F ?
				<RESULTS>

NOTES:

- a) REFER TO EQUATION (3)
- b) REFER TO EQUATION (1)
- c) REFER TO EQUATION (2)

FB 21: YIELD-PER-RECRUIT

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
4.2.2	RESULTS:			
4.2.2.1	YIELD/RECRUIT FOR AGE t_c			Y<c>: (x)
4.2.2.2	YIELD/RECRUIT FOR AGE t_r			Y<r>: (x)
				NEXT F ?
5.	<u>OPTIONS:</u>			
5.1	FOR CASE I, II, III:			
5.1.1	REVIEW RESULTS		E	<RESULTS>
5.1.2	NEW INPUT OF ALL CONSTANTS		f c	* FB 21 *
5.1.3	REVIEW MENU		C	MENU:
5.2	FOR CASE II & III:			
5.2.1	CHANGE INPUT OF t_c AND t_r ONLY		I/J	T<c> ?
5.2.2	COMPUTE SLOPE OF Y/R-CURVE FOR GIVEN F		F	SLOPE<Y/R>:
6.	<u>DETERMINATION OF $F_{0.1}$</u> [REQUIREMENT: INPUT OF CONSTANTS VIA "I" OR "J"]		F	SLOPE<Y/R>
				ENTER: F ?
6.1	COMPUTE SLOPE AT F=0 RESULT: SL. AT F=0	0	R/S	SL.: (x) NEXT F ?
6.2	TRY VARIOUS F-VALUES TO IDENTIFY THE POINT THAT PRODUCES A SLOPE EQUAL TO SL.(F=0)/10 (=F _{0.1})	F	R/S	SL.: (x)

REGISTERS, STATUS, FLAGS

PROGR. NAME: FB 21 (Yield per Recruit [Special VBGF])

STATUS : REG. (PROGR.): 148
 SIZE (MIN.) : 018 SIZE (MAX.): -

FLAGS : 0, 5 - 10

ASSIGNMENTS:

A: GENERAL COMMANDS

INITIALIZE : (f)c
 REVIEW RESULTS : E
 RECALL MENU : C

B: SPECIAL COMMANDS

SIMPLIFIED VERSION (I): H
 ORIGINAL VERSION (II): I
 JONES VERSION (III): J
 SLOPE OF Y/R-CURVE : F

REGISTERS :

SUB- PROGR.:	H	I+J	F
00 :	-	[u]	[u]
01 :	[u]	[u]	[u]
02 :	[u]	[u]	[u]
03 :	[u]	[u]	[u]
04 :	E	F	[u]
05 :	-	[u]	[u]
06 :	-	[u]	[u]
07 :	[u]	[u]	-
08 :	-	[u]	[u]
09 :	[u]	[u]	SL.
10 :	[u]	[u]	-
11 :	[u]	[u]	[u]
12 :	[u]	-	[u]
13 :	[u]	[u]	[u]
14 :	[u]	-	-
15 :	-	[u]	-
16 :	-	Y/R<c>	-
17 :	Y'/R<r>	Y/R<r>	-

Program Listing

(FB 21)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01+LBL "FB 21"		57 CF 10		113 STO 13		169 3		225 /	
02+LBL C		58 "ORIGIN"		114 ST- Y		170 *		226 STO 14	
03 CF 21		59+LBL 01		115 RCL 00		171 XEQ 00		227 -3	
04 BEEP		60 CF 00		116 -		172 RCL 09		228 XEQ 01	
05 " * FB 21 * "		61 "F. V."		117 STO 05		173 3		229 3	
06 AVIEW		62 AVIEW		118 X<>Y		174 *		230 XEQ 01	
07 SF 27		63 FS? 55		119 STO 06		175 E+X		231 -1	
08 CLRG		64 XEQ "P"		120 "T(R)"		176 CHS		232 XEQ 01	
09 CF 00		65 PSE		121 XEQ 07		177 XEQ 00		233 RCL 12	
10 CF 05		66 XEQ 10		122 STO 15		178 RCL 07		234 RCL 10	
11 CF 07		67 FIX 2		123 CF 13		179 RCL 04		235 Y+X	
12 CF 08		68 FC? 09		124+LBL 11		180 *		236 RCL 04	
13 PSE		69 GTO 01		125 SF 05		181 RCL 11		237 *	
14 FS? 55		70 FIX 3		126 "Y/R-ESTIN.:"		182 *		238 RCL 07	
15 XEQ "P"		71 "M/K"		127 FS? 55		183 STO 16		239 *	
16+LBL C		72 XEQ 03		128 XEQ 12		184 RCL 13		240 STO 17	
17 "MENU :"		73 STO 10		129 AVIEW		185 RCL 15		241 GTO e	
18 AVIEW		74 1		130 PSE		186 -		242+LBL 01	
19 PSE		75 "c"		131+LBL "U"		187 RCL 02		243 RCL 12	
20 "SIMPLIF. V.: H"		76 XEQ 07		132 "ENTER :"		188 *		244 RCL 09	
21 AVIEW		77 -		133 AVIEW		189 CHS		245 Y+X	
22 PSE		78 STO 12		134 PSE		190 E+X		246 *	
23 PSE		79 GTO 11		135 CLA		191 *		247 1	
24 "ORIGIN. V.: i"		80+LBL 01		136 GTO 01		192 STO 17		248 RCL 14	
25 AVIEW		81 FC? 05		137+LBL "K"		193 GTO e		249 RCL 09	
26 PSE		82 GTO 01		138 "NEXT"		194+LBL 00		250 *	
27 PSE		83 GTO 02		139+LBL 01		195 FC? 10		251 +	
28 "JONES V.: J"		84+LBL 01		140 0		196 XEQ 01		252 /	
29 AVIEW		85 "W(00)"		141 STO 07		197 XEQ 02		253 ST+ 07	
30 PSE		86 XEQ 03		142 FS? 09		198 RTN		254 1	
31 PSE		87 STO 11		143 GTO 09		199+LBL 01		255 ST+ 09	
32 "Y/R-SLOPE : F"		88 "K"		144 "F F ?"		200 1		256 RTN	
33 AVIEW		89 FIX 3		145 PROMPT		201 RCL 08		257+LBL 10	
34 PSE		90 XEQ 06		146 STO 04		202 RCL 06		258 "ENTER CONST.:"	
35 PSE		91 STO 01		147 RCL 02		203 *		259 AVIEW	
36 "MENU : C"		92 "H"		148 +		204 CHS		260 "CONSTANTS :"	
37 AVIEW		93 FIX 2		149 STO 03		205 E+X		261 FS? 55	
38 PSE		94 XEQ 06		150 FS? 00		206 -		262 XEQ 12	
39 "INIT.: c"		95 STO 02		151 RTN		207 *		263 PSE	
40 AVIEW		96 FS? 09		152 STO 08		208 RTN		264 RTN	
41 PSE		97 GTO 11		153 1		209+LBL 02		265+LBL 12	
42 "REV. RES.: E"		98 SF 13		154 XEQ 08		210 RCL 08		266 SF 21	
43 PROMPT		99 FS? 10		155 RCL 01		211 /		267 ADV	
44 GTO C		100 GTO 01		156 RCL 05		212 ST+ 07		268 ACA	
45+LBL H		101 "T(MAX)"		157 *		213 RCL 01		269 PRBUF	
46 "SIMPLIF"		102 XEQ 03		158 CHS		214 ST+ 08		270 CF 21	
47 SF 09		103 STO 10		159 STO 09		215 RTN		271 RTN	
48 CF 10		104+LBL 01		160 E+X		216+LBL 09		272+LBL 06	
49 GTO 01		105 "T(0)"		161 3		217 1		273 FS? 55	
50+LBL J		106 XEQ 07		162 *		218 STO 09		274 "F "	
51 "JONES"		107 STO 00		163 CHS		219 STO 07		275+LBL 07	
52 SF 10		108+LBL 02		164 XEQ 08		220 "F E ?"		276 FS? 55	
53 CF 09		109 RCL 10		165 RCL 09		221 PROMPT		277 "F "	
54 GTO 01		110 SF 13		166 2		222 STO 04		278+LBL 03	
55+LBL I		111 "T(c)"		167 *		223 -		279 FS? 55	
56 CF 09		112 XEQ 07		168 E+X		224 RCL 10		280 XEQ 04	

Program Listing

(FB 21 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
281	"F ?"	337	-1	393	LBL E	449	ACA		
282	PROMPT	338	XEQ 02	394	FS? 06	450	SF 13		
283	FS? 55	339	RCL 13	395	SF 07	451	ACX		
284	XEQ 05	340	RCL 15	396	FS? 09	452	CF 13		
285	RTN	341	-	397	GTO 02	453	"> :"		
286	LBL 04	342	RCL 02	398	"Y(c): "	454	LBL 00		
287	SF 21	343	*	399	ARCL 16	455	ACA		
288	ACA	344	CHS	400	AVIEW	456	RCL IND Y		
289	CF 21	345	E+X	401	PSE	457	ACX		
290	RTN	346	RCL 11	402	PSE	458	PRBUF		
291	LBL 05	347	*	403	LBL 02	459	RTN		
292	SF 21	348	ST* 09	404	"Y"	460	LBL "P"		
293	CLA	349	FS? 55	405	FS? 09	461	SF 21		
294	"F :"	350	GTO 01	406	"I*"	462	ADV		
295	ACA	351	"SL. : "	407	"I(R): "	463	ADV		
296	ACX	352	ARCL 09	408	ARCL 17	464	SF 12		
297	PRBUF	353	AVIEW	409	AVIEW	465	ACA		
298	CF 21	354	PSE	410	PSE	466	PRBUF		
299	RTN	355	GTO "M"	411	FS? 09	467	CF 21		
300	LBL F	356	LBL 01	412	GTO 02	468	CF 12		
301	FC? 09	357	SF 21	413	FC? 07	469	.END.		
302	GTO 01	358	ADV	414	STOP				
303	"WRONG VERS."	359	"FOR F :"	415	GTO 02				
304	AVIEW	360	4	416	LBL 01				
305	PSE	361	STO Y	417	XEQ "Z"				
306	GTO C	362	XEQ 00	418	LBL 02				
307	LBL 01	363	"SLOPE :"	419	SF 06				
308	CF 21	364	9	420	GTO "K"				
309	SF 00	365	STO Y	421	LBL "Z"				
310	"SLOPE (Y/R) :"	366	XEQ 00	422	SF 21				
311	AVIEW	367	CF 21	423	ADV				
312	FS? 55	368	GTO "M"	424	"F"				
313	XEQ 12	369	LBL 02	425	FS? 09				
314	PSE	370	RCL 02	426	"E"				
315	RCL 05	371	RCL 07	427	"F :"				
316	RCL 01	372	+	428	4				
317	*	373	RCL 03	429	ENTER↑				
318	CHS	374	RCL 07	430	XEQ 00				
319	E+X	375	+	431	FS? 09				
320	STO 12	376	X↑2	432	GTO 02				
321	XEQ "U"	377	/	433	16				
322	GTO 01	378	RCL 08	434	"c"				
323	LBL "M"	379	*	435	XEQ 01				
324	SF 00	380	*	436	LBL 02				
325	XEQ "K"	381	ST+ 09	437	17				
326	LBL 01	382	RCL 01	438	"R"				
327	1	383	ST+ 07	439	XEQ 01				
328	STO 08	384	RCL 12	440	CF 21				
329	0	385	ST* 08	441	RTN				
330	STO 09	386	RTN	442	LBL 01				
331	1	387	LBL e	443	ENTER↑				
332	XEQ 02	388	CF 06	444	ASTO X				
333	-3	389	CF 07	445	"Y"				
334	XEQ 02	390	FIX 3	446	FS? 09				
335	3	391	FS? 55	447	"I*"				
336	XEQ 02	392	GTO 01	448	"I/R <"				

EXAMPLE 3.21

(See also p. 123-125 Examples 8.1 and 8.3 in manual)

* FB 21 *

* FB 21 *

SIMPLIF. V.

CONSTANTS :

M/K : 1.900

c : 0.380

Y/R-ESTIM.:

E : 0.100

Y*/R ("r") : 0.009

E : 0.200

Y*/R ("r") : 0.017

E : 0.300

Y*/R ("r") : 0.023

E : 0.500

Y*/R ("r") : 0.030

E : 0.700

Y*/R ("r") : 0.031

E : 1.000

Y*/R ("r") : 0.022

JONES. V.

CONSTANTS :

W(00) : 64.00

K : 1.000

M : 2.00

t(o) : -0.20

t(c) : 0.20

t(r) : 0.20

Y/R-ESTIM.

F : 0.500

Y/R ("c") : 2.247

Y/R ("r") : 2.247

F : 1.000

Y/R ("c") : 3.199

Y/R ("r") : 3.199

F : 2.000

Y/R ("c") : 3.769

Y/R ("r") : 3.769

F : 4.000

Y/R ("c") : 3.691

Y/R ("r") : 3.691

F : 5.000

Y/R ("c") : 3.566

Y/R ("r") : 3.566

EXAMPLE 3.21 (Cont.)

(See also p. 123-125, Example 8.2 in manual)

* FB 21 *

ORIGIN. V.

CONSTANTS :

W(00) : 12,226.00

K : 0.154

M : 0.33

t(max) : 10.00

t(o) : -0.67

t(c) : 2.00

t(r) : -0.67

Y/R-ESTIM. :

F : 0.500

Y/R ("c") : 700.211

Y/R ("r") : 293.431

F : 1.000

Y/R ("c") : 660.904

Y/R ("r") : 273.830

F : 0.200

Y/R ("c") : 591.955

Y/R ("r") : 245.263

F : 0.300

Y/R ("c") : 671.903

Y/R ("r") : 278.387

Additional Example:

Computation of biomass per recruit (B/R_r)

Same constants as in Jones' version

F = 5.000

Y/R = 3.566

$B/R_r^r = 3.566/5 = 0.713$

* FB 21 *

ORIGIN. V.

CONSTANTS :

W(00) : 12,226.00

K : 0.154

M : 0.33

t(max) : 10.00

t(o) : -0.67

t(c) : 2.00

t(r) : -0.67

Y/R-ESTIM. :

SLOPE (Y/R) :

FOR F : 0.00

SLOPE : 3,140.55

FOR F : 0.30

SLOPE : 141.62

FOR F : 0.20

SLOPE : 409.03

FOR F : 0.25

SLOPE : 245.92

FOR F : 0.22

SLOPE : 334.74

FOR F : 0.23

SLOPE : 302.42

3.22: PROGRAM DESCRIPTION FB 22

Yield-per-Recruit via Incomplete β -Function

Yield-per-recruit, as shown by Jones (1957), can be computed, when growth conforms to the special VBGF, by using

$$Y/R_r = (F/K) \cdot e^{Zr_1} \cdot e^{-Mr_2} W_{\infty} \cdot \{ \beta(X, P, Q) \} \quad \dots 1)$$

where $X = e^{-Kr_1}$, $P = Z/K$, $Q = b + 1$ (b being the exponent of the length-weight relationship), β is the symbol of the incomplete beta function, and where $r_1 = t - t_0$ and $r_2 = t - t_r$. Note here that b may be $\neq 3$ (Jones^c 1957, Wilimovsky^a and Wicklund^r 1963, Ricker 1975).

When the generalized VBGF is used to describe growth, yield-per-recruit can be computed from

$$Y/R_r = \frac{F}{KD} \cdot e^{Zr_1} \cdot e^{-Mr_2} W_{\infty} \cdot \{ \beta(X, P, Q) \} \quad \dots 2)$$

where $X = e^{-KDr_1}$, $P = Z/KD$, $Q = (b/D) + 1$ and r_1 and r_2 are defined as above.

The routine which estimates the values of the incomplete beta function is taken from Program 00425 D, submitted by R.H. Shudde to the U.S. HP 67/97 User's Library.

FB 22: YIELD-PER-RECRUIT VIA INCOMPLETE β -FUNCTION

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM			* FB 22 *
1.	DISPLAY OF MENU			MENU:
1.1	SPECIAL VBGF			SPEC. VBGF : A
1.2	GENERALIZED VBGF			GENER. VBGF: B
1.3	}			MENU : C
1.4	} SEE GENERAL			INIT. : c
1.5	} INSTRUCTIONS			REV. RES. : E
2.	SELECT:			
2.1	SPECIAL VBGF		A	W<00> ?
2.2	GENERALIZED VBGF		B	W<00> ?
3.	ENTER CONSTANTS:			
3.1	ASYMPTOTIC WEIGHT	W	R/S	K ?
3.2	K (ANNUAL BASIS)	K^∞	R/S	D ?
3.3	D (THIS STEP IS OMITTED WHEN SPEC. VBGF IS USED, I.E. PROGRAM SETS D = 1)	D	R/S	b* ?
3.4	EXPONENT OF L-W REL.	b	R/S	M ?
3.5	NATURAL MORTALITY	M	R/S	T<0> ?
3.6	VALUE OF t	t^o	R/S	T<C> ?
3.7	AGE AT FIRST CAPTURE	t^o	R/S	T<R> ?
3.8	AGE AT RECRUITMENT	t^c_r	R/S	F ?
4.	ENTER FISHING MORTALITY	F	R/S	<RESULTS>
5.	DISPLAY OF RESULTS			
5.1	β - VALUE			: (x)
5.2	YIELD PER RECRUIT AT AGE t^c			Y<C>: (x)
5.3	YIELD PER RECRUIT AT AGE t^c_r			Y<R>: (x)
5.4	GO TO STEP 4.			NEXT F ?
6.	OPTIONS:			
6.1	CHANGE ALL CONSTANTS, DO AND GO TO STEP 2.		f c A OR B	* FB 2 *
6.2	CHANGE ONLY t^c AND t^c_r , DO AND CONTINUE AT STEP 3.7		A OR B	T<C> ?

REGISTERS, STATUS, FLAGS

PROGR. NAME: FB 22 (Yield per Recruit via Incomplete β - Function)

STATUS : REG. (PROGR.): 109
 SIZE (MIN.) : 024 SIZE (MAX.): -

FLAGS : 5 - 7, 10

ASSIGNMENTS:

A: GENERAL COMMANDS

B: SPECIAL COMMANDS

INITIALIZE : (f)c
REVIEW RESULTS : E
RECALL MENU : C

SPECIAL VBGF : H
GENERALIZED VBGF : I

REGISTERS :

SUB- PROGR.:	A	B
00 :	[u]	[u]
01 :	[u]	[u]
02 :	[u]	[u]
03 :	[u]	[u]
04 :	[u]	[u]
05 :	[u]	[u]
06 :	[u]	[u]
07 :	[u]	[u]
08 :	[u]	[u]
09 :	[u]	[u]
10 :	[u]	[u]
11 :	[u]	[u]
12 :	[u]	[u]
13 :	[u]	[u]
14 :	[u]	[u]
15 :	D	D
16 :	[u]	[u]
17 :	F	F
18 :	[u]	[u]
19 :	[u]	[u]
20 :	[u]	[u]
21 :		
22 :	Y/R<c>	Y/R<c>
23 :	Y/R<r>	Y/R<r>

Program Listing

(FB 22)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01*LBL "FB 22"		57 STO 14		113 STO 18		169 RCL 07		225 /	
02*LBL c		58 *K"		114 RCL 19		170 *		226 STO 21	
03 CF 21		59 FIX 3		115 *		171 RCL 06		227 RCL 14	
04 BEEP		60 XEQ 06		116 CHS		172 +		228 *	
05 " * FB 22 *"		61 STO 13		117 E+X		173 STO 07		229 RCL 17	
06 AVIEW		62 FS? 10		118 STO 03		174 RCL 08		230 *	
07 SF 27		63 GTO 01		119 RCL 16		175 1		231 RCL 18	
08 SREG 04		64 1		120 RCL 15		176 +		232 /	
09 CLRG		65 GTO 02		121 /		177 STO 08		233 RCL 19	
10 CF 05		66*LBL 01		122 1		178 RCL 02		234 RCL 17	
11 CF 07		67 "D"		123 +		179 RCL 08		235 RCL 00	
12 CF 08		68 FIX 2		124 STO 02		180 -		236 +	
13 FC? 10		69 XEQ 06		125 RCL 17		181 *		237 *	
14 PSE		70*LBL 02		126 RCL 00		182 RCL 01		238 E+X	
15 FS? 55		71 STO 15		127 +		183 RCL 08		239 *	
16 XEQ "P"		72 "b"		128 RCL 16		184 +		240 STO 22	
17*LBL C		73 XEQ 07		129 /		185 RCL 08		241 RCL 20	
18 *MENU : "		74 STO 16		130 STO 01		186 +		242 RCL 00	
19 AVIEW		75 "M"		131 1		187 / "		243 *	
20 PSE		76 XEQ 06		132 STO 07		188 LASTX		244 CHS	
21 *SPEC. VBGF : A"		77 STO 00		133 STO 06		189 1		245 E+X	
22 AVIEW		78 SF 13		134 STO 04		190 -		246 *	
23 PSE		79 *T<O>"		135 0		191 /		247 STO 23	
24 PSE		80 XEQ 08		136 STO 08		192 RCL 03		248 GTO e	
25 *GENER. VBGF: B"		81 STO 10		137 STO 05		193 *		249*LBL 10	
26 AVIEW		82*LBL 00		138*LBL "L"		194 ENTER+		250 *ENTER CONST.:"	
27 PSE		83 SF 13		139 STO 09		195 ENTER+		251 AVIEW	
28 PSE		84 *T<c>"		140 RCL 01		196 RCL 04		252 *CONSTANTS :"	
29 *MENU : C"		85 XEQ 08		141 RCL 08		197 *		253 FS? 55	
30 AVIEW		86 STO 11		142 +		198 RCL 05		254 XEQ 12	
31 PSE		87 RCL 10		143 ENTER+		199 +		255 PSE	
32 *INIT.: c"		88 -		144 ENTER+		200 STO 04		256 RTN	
33 AVIEW		89 STO 19		145 RCL 02		201 X<>Y		257*LBL 12	
34 PSE		90 RCL 11		146 +		202 RCL 06		258 SF 21	
35 *REV. RES.: E"		91 *T<R>"		147 *		203 *		259 ADV	
36 PROMPT		92 XEQ 08		148 RCL 01		204 RCL 07		260 ACA	
37 GTO C		93 STO 12		149 RCL 08		205 +		261 PRBUF	
38*LBL B		94 -		150 +		206 STO 06		262 CF 21	
39 *GEN"		95 STO 20		151 RCL 08		207 X*0?		263 RTN	
40 SF 10		96 CF 13		152 +		208 /		264*LBL 06	
41 GTO 01		97 SF 05		153 /		209 RND		265 FS? 55	
42*LBL A		98 *RESULTS :"		154 LASTX		210 RCL 09		266 "f "	
43 CF 10		99 FS? 55		155 1		211 X<>Y		267*LBL 07	
44 *SPEC"		100 XEQ 12		156 +		212 X*Y?		268 FS? 55	
45*LBL 01		101 CLA		157 /		213 GTO "L"		269 "f "	
46 "f. VBGF"		102 GTO 01		158 RCL 03		214 RCL 03		270*LBL 08	
47 AVIEW		103*LBL "K"		159 *		215 RCL 01		271 FS? 55	
48 FS? 55		104 *NEXT"		160 CHS		216 Y+X		272 "f "	
49 XEQ "P"		105*LBL 01		161 ENTER+		217 *		273*LBL 03	
50 PSE		106 FIX 3		162 ENTER+		218 1		274 FS? 55	
51 XEQ 10		107 "f f ?"		163 RCL 05		219 RCL 03		275 XEQ 04	
52 FIX 2		108 PROMPT		164 *		220 -		276 "f ?"	
53 FS? 05		109 STO 17		165 RCL 04		221 RCL 02		277 PROMPT	
54 GTO 00		110 RCL 13		166 +		222 Y+X		278 FS? 55	
55 *W<00>"		111 RCL 15		167 STO 05		223 *		279 XEQ 05	
56 XEQ 03		112 *		168 CLX		224 RCL 01		280 RTN	

Program Listing

(FB 22 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
281	LBL 04	337	5				
282	SF 21	338	ACCHR				
283	ACA	339	"t :"				
284	CF 21	340	XEQ 02				
285	RTN	341	22				
286	LBL 05	342	"c"				
287	SF 21	343	XEQ 01				
288	CLA	344	23				
289	"t :"	345	"R"				
290	ACA	346	XEQ 01				
291	ACX	347	CF 21				
292	PRBUF	348	RTN				
293	CF 21	349	LBL 01				
294	RTN	350	ENTER↑				
295	LBL e	351	ASTO X				
296	CF 06	352	"Y/R <"				
297	CF 07	353	ACA				
298	FIX 3	354	SF 13				
299	FS? 55	355	ACX				
300	GTO 01	356	CF 13				
301	LBL E	357	"> :"				
302	FS? 06	358	LBL 02				
303	SF 07	359	ACA				
304	" : "	360	RCL IND Y				
305	ARCL 21	361	ACX				
306	AVIEW	362	PRBUF				
307	PSE	363	RTN				
308	PSE	364	LBL "P"				
309	"Y(c): "	365	SF 21				
310	ARCL 22	366	ADV				
311	AVIEW	367	ADV				
312	PSE	368	SF 12				
313	PSE	369	ACA				
314	"Y(R) : "	370	PRBUF				
315	ARCL 23	371	CF 21				
316	AVIEW	372	CF 12				
317	PSE	373	END.				
318	FC? 07						
319	STOP						
320	GTO 02						
321	LBL 01						
322	XEQ "Z"						
323	LBL 02						
324	SF 06						
325	GTO "K"						
326	LBL "Z"						
327	SF 21						
328	ADV						
329	17						
330	ENTER↑						
331	"F :"						
332	XEQ 02						
333	CLA						
334	21						
335	ENTER↑						
336	ENTER↑						

EXAMPLE 3.22

(See also p. 126 in manual)

Data from Appendix I,
Tab. 8.1 & 8.2

Data from Appendix I,
Tab. 8.2

* FB 22 *

SPEC. VBGF

CONSTANTS :

W(00) : 162.25

K : 0.150

b* : 3.300

M : 0.300

t(c) : -0.795

t(c) : 2.350

t(r) : 2.350

RESULTS :

F : 0.100

B : 0.018

Y/R ("c") : 6.773

Y/R ("r") : 6.773

F : 0.400

B : 0.003

Y/R ("c") : 9.867

Y/R ("r") : 9.867

F : 0.800

B : 3.375-04

Y/R ("c") : 9.287

Y/R ("r") : 9.287

F : 1.200

B : 5.967-05

Y/R ("c") : 8.666

Y/R ("r") : 8.666

F : 1.600

B : 1.209-05

Y/R ("c") : 8.235

Y/R ("r") : 8.235

F : 2.000

B : 2.648-06

Y/R ("c") : 7.936

Y/R ("r") : 7.936

* FB 22 *

GEN. VBGF

CONSTANTS :

W(00) : 85.95

K : 0.582

D : 0.47

b* : 3.30

M : 0.30

t(c) : -2.04

t(c) : 2.39

t(r) : 2.39

RESULTS :

F : 0.100

B : 0.036

Y/R ("c") : 6.626

Y/R ("r") : 6.626

F : 0.400

B : 0.004

Y/R ("c") : 10.433

Y/R ("r") : 10.433

F : 0.800

B : 3.085-04

Y/R ("c") : 10.138

Y/R ("r") : 10.138

F : 1.500

B : 6.742-06

Y/R ("c") : 9.230

Y/R ("r") : 9.230

F : 2.000

B : 5.274-07

Y/R ("c") : 8.819

Y/R ("r") : 8.819

3.23: PROGRAM DESCRIPTION FB 23

Conversion Factor "k"

Under equilibrium conditions, the proportion in the total stock (all fish of age t_c and older) of fish of age t_k and older is given by

$$k = \frac{\exp(-Zr_3) \left[\frac{1}{Z} - \frac{3 \exp(-Kr_2)}{Z + K} + \frac{3 \exp(-2Kr_2)}{Z + 2K} - \frac{\exp(-3Kr_2)}{Z + 3K} \right]}{\left[\frac{1}{Z} - \frac{3 \exp(-Kr_1)}{Z + K} + \frac{3 \exp(-2Kr_1)}{Z + 2K} - \frac{\exp(-3Kr_1)}{Z + 3K} \right]} \dots 1)$$

where $r_1 = t_c - t_o$
 $r_2 = t_c - t_o$
 and $r_3 = t_k - t_o$
 with the parameters K and t_o pertaining to the special VBGF.

Operating Limits and Warnings

Use only in conjunction with the special VBGF (i.e., with $D = 1$); also note that model is strictly applicable only under equilibrium conditions, i.e. in conjunction with a stable age distribution.

FB 23: CONVERSION FACTOR "k"

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM (NO MENU)			* FB 23 *
1.	ENTER CONSTANTS:			ENTER CONST.: K ?
1.1	K (ANNUAL BASIS)	K	R/S	M ?
1.2	NATURAL MORTALITY	M	R/S	T<0> ?
1.3	VALUE OF t	t	R/S	T<C> ?
1.4	MEAN AGE AT FIRST CAPTURE	t^o	R/S	T<K> ?
1.5	AGE t_k	t_k^c	R/S	F ?
2.	ENTER FISHING MORTALITY (RESULT: k-VALUE)	F	R/S	PLEASE WAIT >K<: (x) :
3.	FOR A NEW VALUE OF "F", PRESS ^{a)} AND GO TO STEP 2.		R/S	NEXT F ?
4.	OPTIONS:			
4.1	TO REVIEW RESULTS, PRESS		E	>K<: (x)
4.2	TO ENTER A NEW SET OF CONSTANTS, PRESS AND CONTINUE AT STEP 1.		f c	* FB 23 *

a) NOTE: THIS STEP IS SKIPPED IF A PRINTER IS CONNECTED. INSTEAD, THE PROGRAM AUTOMATICALLY RETURNS TO STEP 2.

REGISTERS, STATUS, FLAGS

PROGR. NAME: FB 23 (Conversion Factor "k")

STATUS : REG. (PROGR.): 62
SIZE (MIN.) : 015 SIZE (MAX.): -

FLAGS : 6, 7

ASSIGNMENTS:

A: GENERAL COMMANDS

B: SPECIAL COMMANDS

INITIALIZE : (f)c

REVIEW RESULTS : E

REGISTERS :

00 : [u]
01 : [u]
02 : M
03 : Z
04 : F
05 : [u]
06 : [u]
07 : [u]
08 : [u]
09 : [u]
10 : [u]
11 : -
12 : k
13 : [u]
14 : [u]

Program Listing

(FB 23)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01	LBL "FB 23"	57	LBL 05	113	-1	169	ADV		
02	LBL c	58	SF 21	114	LBL 09	170	"F"		
03	CF 21	59	CLA	115	RCL 09	171	4		
04	BEEP	60	"F :"	116	RCL 10	172	ENTER†		
05	" * FB 23 *"	61	ACA	117	*	173	XEQ 00		
06	AVIEW	62	ACX	118	CHS	174	SF 13		
07	SF 27	63	PRBUF	119	ETX	175	"K"		
08	CLRG	64	CF 21	120	*	176	12		
09	SREG 07	65	RTN	121	RCL 03	177	ENTER†		
10	PSE	66	LBL 01	122	RCL 09	178	XEQ 00		
11	FS? 55	67	"RESULTS :"	123	+	179	CF 13		
12	XEQ "P"	68	FS? 55	124	/	180	CF 21		
13	XEQ 10	69	XEQ 12	125	ST+ 07	181	RTN		
14	"K"	70	CLA	126	RCL 01	182	LBL 00		
15	FIX 3	71	GT0 01	127	ST+ 09	183	"F :"		
16	XEQ 06	72	LBL "K"	128	RTN	184	ACA		
17	ST0 01	73	"NEXT"	129	LBL 10	185	RCL IND Y		
18	"M"	74	LBL 01	130	"ENTER CONST.:"	186	ACX		
19	FIX 2	75	"F F ?"	131	AVIEW	187	PRBUF		
20	XEQ 06	76	PROMPT	132	"CONSTANTS :"	188	RTN		
21	ST0 02	77	ST0 04	133	FS? 55	189	SF 13		
22	SF 13	78	"PLEASE WAIT"	134	XEQ 12	190	LBL "P"		
23	"T<0>"	79	AVIEW	135	PSE	191	SF 21		
24	XEQ 03	80	RCL 02	136	RTN	192	ADV		
25	ST0 00	81	+	137	LBL 12	193	ADV		
26	"T<c>"	82	ST0 03	138	SF 21	194	SF 12		
27	XEQ 03	83	CLS	139	ADV	195	ACA		
28	ST0 13	84	RCL 06	140	ACA	196	PRBUF		
29	X<>Y	85	ST0 10	141	PRBUF	197	CF 21		
30	-	86	XEQ 08	142	CF 21	198	CF 12		
31	ST0 05	87	RCL 07	143	RTN	199	END.		
32	"T<K>"	88	CLS	144	LBL e				
33	XEQ 03	89	ST0 08	145	CF 06				
34	ST0 14	90	RCL 05	146	CF 07				
35	RCL 00	91	ST0 10	147	FIX 2				
36	-	92	XEQ 08	148	FS? 55				
37	ST0 06	93	RCL 03	149	GT0 01				
38	ST0 10	94	RCL 14	150	LBL E				
39	CF 13	95	RCL 13	151	FS? 06				
40	GT0 01	96	-	152	SF 07				
41	LBL 06	97	*	153	">K< : "				
42	FS? 55	98	CHS	154	ARCL 12				
43	"F "	99	ETX	155	AVIEW				
44	LBL 03	100	RCL 08	156	PSE				
45	FS? 55	101	*	157	PSE				
46	XEQ 04	102	RCL 07	158	FC? 07				
47	"F ?"	103	/	159	STOP				
48	PROMPT	104	ST0 12	160	GT0 02				
49	FS? 55	105	GT0 e	161	LBL 01				
50	XEQ 05	106	LBL 08	162	FS? 55				
51	RTN	107	1	163	XEQ "Z"				
52	LBL 04	108	XEQ 09	164	LBL 02				
53	SF 21	109	-3	165	SF 06				
54	ACA	110	XEQ 09	166	GT0 "K"				
55	CF 21	111	3	167	LBL "Z"				
56	RTN	112	XEQ 09	168	SF 21				

EXAMPLE 3.23

(See also p. 128 in manual)

* FB 23 *

CONSTANTS :

K : 1.000

M : 1.00

t(o) : -0.20

t(c) : 0.20

t(k) : 1.00

RESULTS :

F : 0.00

k : 0.55

F : 1.00

k : 0.32

F : 2.00

k : 0.17

F : 0.50

k : 0.42

3.24: PROGRAM DESCRIPTION FB 24

Stock-recruitment curve of Beverton and Holt

The stock-recruitment relationship proposed by Beverton and Holt (1957) has the form

$$R = \frac{1}{\alpha' + \beta'/P}, \quad \dots 1)$$

where P is the size of the parental stock and R is the number of recruits, while α' (alpha') and β' (beta') are parameters estimated by linear regression (see below). When P and R are expressed in the same units, the formula can be rewritten as

$$R = \frac{1}{1-A (1-P/P_r)} \quad \dots 2)$$

where $A = 1-\beta'$ and $\alpha' = A/P_r$, P_r being the replacement abundance. The curve is fitted by means of:

$$\frac{P}{R} = \beta' + \alpha' P, \quad \dots 3)$$

that is by regressing P/R on P. The conversion of HM-values to the corresponding arithmetic mean values (AM) follows the procedure outlined by Ricker (1975).

Operating Limits and Warnings

The AM-values obtained through conversion from the HM-values are approximative (see Ricker 1975, p. 292). When a negative value of β' is obtained, the program automatically deletes the values of R and P associated with the lowest P/R ratio and recalculates α' and β' .

FB 24: STOCK RECRUITMENT CURVE OF BEVERTON AND HOLT

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM DATA INPUT			* FB 24 * DATA INP.: NO. OF ROWS ?
1.	ENTER NO. OF ROWS	k	R/S	1. ROW:
1.2	ENTER FOR ROW 1,2..k			P ?
1.3	SPAWNING STOCK SIZE	P	R/S	R ?
1.4	NUMBER OF RECRUITS	R	R/S	2. (3...k) ROW:
	NOTE: WHEN A NEGATIVE VALUE OF β' IS OBTAINED THE PROGRAM DELETES THE VALUES OF P AND R ASSOCIATED WITH THE LOWEST P/R RATIO, DISPLAYS THE NUMBER OF THE DELETED ROW, AND RECALCULATES RESULTS.			DEL. ROW NO.: (x) PLEASE WAIT <RESULTS>
2.	DISPLAY OF RESULTS			
2.1	NUMBER OF ROWS USED FOR REGRESSION (n)			N: (x)
2.2	COEFFICIENT OF DETERMINATION (r^2)			R^2 : (x)
2.3	α'			<a>: (x)
2.4	β'			: (x)
3.	DISPLAY OF MENU:			MENU:
3.1	ESTIMATES OF R_{HM} AND R_{AM}			$R_{HM,AM}$: A
3.2	ESTIMATES OF A AND P (R_{HM})			A, P<R> : B
3.3	DISPLAY OF MENU			MENU : C
3.4	INITIALIZE			INIT. : c
3.5	REVIEW DATA			REV.DATA: D
3.6	REVIEW RESULTS			REV.RES.: E
4.	TO OBTAIN ESTIMATES OF R_{HM} AND R_{AM} PRESS		A	ENTER: P ?
4.1	ENTER P	P	R/S	(RESULTS)
4.2	DISPLAY OF RESULTS			
4.2.	ESTIMATE OF R_{HM}			R_{HM} : (x)
4.2.2	ESTIMATE OF R_{AM}			R_{AM} : (x)
4.3	FOR ANOTHER VALUE OF P PRESS AND GO TO STEP 4.1		-R/S	NEXT P ?

FB 24: STOCK RECRUITMENT CURVE OF BEVERTON AND HOLT

USER INSTRUCTIONS (cont.)

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
5.	IF P AND R ARE EXPRESSED IN THE SAME UNITS, PRESS TO OBTAIN:		B	<RESULTS>
5.1	ESTIMATE OF A			A: (x)
5.2	ESTIMATE OF P _r (HM)			P<R>: (x)

NOTE: SUB-PROGRAMS "A" AND "B" CAN BE CALLED IN ANY ORDER, BUT NOT BEFORE STEP 2.4 HAS BEEN REACHED.

REGISTERS, STATUS, FLAGS

```
-----
PROGR. NAME:          FB 24  (Stock-Recr. Curve of Beverton & Holt)
-----
STATUS      :          REG. (PROGR.): 161
                  SIZE (MIN.)   :  (k*2)+16          SIZE (MAX.): 158
-----
FLAGS       :          5 - 7, 9, 10
-----
```

ASSIGNMENTS:

A: <u>GENERAL COMMANDS</u>	B: <u>SPECIAL COMMANDS</u>
INITIALIZE : (f)c	ESTIM. OF R <HM & AM>: A
REVIEW RESULTS : E	ESTIM. OF A AND P<r> : B
RECALL MENU : C	
REVIEW DATA : D	

REGISTERS :

```
-----
SUB-
PROGR.:          A          B
00 :      [u]      [u]
01 :      [u]      P          results
02 :      [u]      R<HM>      are
03 :      r2      R<AM>      stored
04 :      < α >    [u]          in
05 :      < β >    [u]          X-register
06 :      [u]      [u]
07 :      [u]      [u]
08 :      [u]      [u]
09 :      [u]      [u]
10 :      [u]
11 :      [u]
12 :      [u]
13 :      [u]
14 :      [u]
15 :      n
16 :      P(1)
17 :      R(1)
      .
      .
      P(k)
      R(k)
-----
```

NOTE: "k" REPRESENTS NUMBER OF CASES (= NO. OF ROWS).

Program Listing

(FB 24)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01	LBL "FB 24"	57	XEQ 05	113	PROMPT	169	ST+	225	"DEL. :"
02	LBL c	58	LBL 02	114	STO IND Y	170	X<Y	226	AVIEW
03	CF 21	59	X<Y	115	FC? 06	171	RCL 09	227	PSE
04	BEEP	60	STO IND 06	116	LBL 01	172	X=0?	228	RCL 08
05	" * FB 24 *"	61	ISG 06	117	"MORE "	173	GTO 01	229	14
06	AVIEW	62	X<Y	118	LBL 07	174	X<Y?	230	-
07	SF 27	63	STO IND 06	119	"PREVIEW?"	175	GTO 02	231	2
08	SREG 10	64	FS?C 09	120	XEQ 14	176	LBL 01	232	/
09	CLRG	65	GTO 01	121	X=0?	177	X<Y	233	FIX 0
10	FC? 55	66	ISG 06	122	GTO D	178	STO 09	234	"ROW NO. : "
11	GTO 01	67	GTO "R"	123	"RESULTS ?"	179	RCL 06	235	ARCL X
12	SF 21	68	LBL 01	124	XEQ 14	180	INT	236	AVIEW
13	SF 12	69	CF 06	125	X=0?	181	1	237	PSE
14	ADV	70	CLA	126	GTO D	182	-	238	1
15	ADV	71	RCL 00	127	GTO "K"	183	STO 08	239	RCL 08
16	ACA	72	INT	128	LBL 10	184	LBL 02	240	ST+ Y
17	PRBUF	73	1	129	"F : "	185	ISG 06	241	0
18	ADV	74	-	130	ARCL IND X	186	GTO "L"	242	STO IND Y
19	CF 21	75	STO 00	131	AVIEW	187	RCL 14	243	STO IND Z
20	CF 12	76	GTO 07	132	PSE	188	RCL 10	244	GTO "K"
21	LBL 01	77	LBL D	133	RTN	189	RCL 12	245	LBL 01
22	FIX 0	78	CF 06	134	LBL 14	190	*	246	0
23	"DATA INP.:"	79	CLA	135	AVIEW	191	RCL 15	247	STO 02
24	AVIEW	80	XEQ 05	136	TONE 7	192	/	248	XEQ "U"
25	PSE	81	"FNO. ?"	137	PSE	193	-	249	2
26	16	82	PROMPT	138	"YES: 1, NO: 0"	194	STO 05	250	5
27	ENTER↑	83	2	139	PROMPT	195	X↑2	251	10↑X
28	ENTER↑	84	*	140	RTN	196	RCL 13	252	/
29	"NO. OF ROWS ?"	85	14	141	LBL 05	197	RCL 12	253	ST+ 06
30	PROMPT	86	+	142	"F ROW "	198	X↑2	254	LBL "M"
31	STO 00	87	FIX 2	143	FC? 06	199	RCL 15	255	RCL IND 06
32	XEQ "U"	88	"P"	144	RTN	200	/	256	X=0?
33	RCL 00	89	XEQ 10	145	"F :"	201	-	257	GTO 01
34	3	90	1	146	AVIEW	202	/	258	XEQ "V"
35	10↑X	91	+	147	RTN	203	RCL 11	259	ST+ 02
36	/	92	STO 07	148	LBL "K"	204	RCL 10	260	LBL 01
37	1	93	"R"	149	"PLEASE WAIT"	205	X↑2	261	ISG 06
38	+	94	XEQ 10	150	AVIEW	206	RCL 15	262	GTO "M"
39	STO 00	95	"CORRECTION ?"	151	XEQ "U"	207	/	263	RCL 01
40	SF 06	96	XEQ 14	152	CLZ	208	-	264	RCL 02
41	"1."	97	X=0?	153	0	209	ST/ 05	265	/
42	XEQ 05	98	GTO 01	154	STO 01	210	/	266	STO 07
43	PSE	99	RCL 07	155	STO 09	211	STO 03	267	"RESULTS :"
44	LBL "R"	100	1	156	LBL "L"	212	RCL 12	268	BEEP
45	"P ?"	101	-	157	RCL IND 06	213	RCL 05	269	AVIEW
46	PROMPT	102	SF 06	158	X=0?	214	RCL 10	270	FC? 55
47	"R ?"	103	"CORR. INF. ?"	159	GTO 01	215	*	271	GTO 01
48	PROMPT	104	AVIEW	160	ISG 06	216	-	272	SF 21
49	ISG 00	105	PSE	161	GTO 02	217	RCL 15	273	ADV
50	GTO 01	106	"P ?"	162	LBL 01	218	/	274	ACA
51	SF 09	107	PROMPT	163	ISG 06	219	STO 04	275	PRBUF
52	GTO 02	108	STO IND Y	164	RCL IND 06	220	X<0?	276	CF 21
53	LBL 01	109	RDN	165	ST+ 01	221	GTO 02	277	LBL 01
54	CLA	110	1	166	1/X	222	GTO 01	278	PSE
55	ARCL 00	111	+	167	X<Y	223	LBL 02	279	CF 09
56	"F."	112	"R ?"	168	ST* Y	224	TONE 7	280	CF 10

Program Listing

(FB 24 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
281	CF 05	337	GTO C	393	RTN	449	SF 13		
282	CF 07	338+LBL A		394+LBL "T"		450	FIX 0		
283	FS? 55	339	SF 09	395 "T")"		451	15		
284	GTO 01	340	CF 10	396+LBL "P"		452	"N "		
285+LBL E		341 "ENTER ."		397 "T . "		453	XEQ 00		
286	FS? 09	342	AVIEW	398	ARCL IND X	454	FIX 3		
287	GTO "0"	343	PSE	399	AVIEW	455	3		
288	FS? 10	344	PSE	400	PSE	456	"R12"		
289	GTO B	345	CLA	401	PSE	457	XEQ 00		
290	FS? 05	346	GTO 01	402	RTN	458	CF 13		
291	SF 07	347+LBL "N"		403+LBL B		459	CLA		
292	FIX 0	348 "NEXT "		404	SF 21	460	4		
293	"N"	349+LBL 01		405	ADV	461	ACCHR		
294	15	350 "FP ?"		406	CF 09	462	39		
295	XEQ "P"	351	PROMPT	407	SF 10	463	ACCHR		
296	FIX 3	352	STO 01	408	1	464	5		
297	"R12"	353	XEQ "V"	409	RCL 04	465	XEQ 01		
298	3	354	STO 02	410	-	466	CLA		
299	XEQ "P"	355	RCL 07	411	"A :"	467	5		
300	"<a"	356	*	412	FS? 55	468	ACCHR		
301	5	357	STO 03	413	ACA	469	39		
302	XEQ "T"	358	CF 05	414	CF 21	470	ACCHR		
303	"<b"	359	CF 07	415	"T "	471	4		
304	4	360	FIX 3	416	ARCL X	472	XEQ 01		
305	XEQ "T"	361	FS? 55	417	AVIEW	473	CF 21		
306	FS? 07	362	GTO 01	418	FS? 55	474	RTN		
307	STOP	363+LBL "0"		419	XEQ 01	475+LBL 01			
308	GTO 02	364	FS? 05	420	PSE	476	"T "		
309+LBL 01		365	SF 07	421	PSE	477+LBL 00			
310	XEQ "Z"	366	"R<HM"	422	RCL 05	478	"T :"		
311+LBL 02		367	2	423	/	479	ACA		
312	SF 05	368	XEQ "T"	424	FC? 55	480	RCL IND X		
313+LBL C		369	"R<AM"	425	GTO 02	481	ACX		
314	"MENU :"	370	3	426	SF 21	482	PRBUF		
315	AVIEW	371	XEQ "T"	427	"P"	483	RTN		
316	PSE	372	FC? 07	428	ACA	484+LBL "U"			
317	PSE	373	STOP	429	SF 13	485	RCL 00		
318	"R <MM,AM) : A"	374	GTO 02	430	"R :"	486	2		
319	AVIEW	375+LBL 01		431	ACA	487	*		
320	PSE	376	XEQ 01	432	CF 13	488	15		
321	PSE	377+LBL 02		433	XEQ 01	489	+		
322	"A, P<R) : B"	378	SF 05	434+LBL 02		490	3		
323	AVIEW	379	GTO "N"	435	"P<R) : "	491	10+X		
324	PSE	380+LBL 01		436	ARCL X	492	/		
325	PSE	381	SF 21	437	PROMPT	493	16		
326	"MENU : C"	382	ADV	438	GTO E	494	+		
327	AVIEW	383	"P"	439+LBL 01		495	STO 06		
328	PSE	384	1	440	SF 21	496	RTN		
329	"INIT.: C"	385	XEQ 00	441	ACX	497+LBL "V"			
330	AVIEW	386	"R<HM)"	442	PRBUF	498	RCL 04		
331	PSE	387	2	443	CF 21	499	X<>Y		
332	"REV. DATA : D"	388	XEQ 00	444	RTN	500	/		
333	AVIEW	389	"R<AM)"	445	SF 21	501	RCL 05		
334	PSE	390	3	446+LBL "Z"		502	+		
335	"REV. RES.: E"	391	XEQ 00	447	SF 21	503	1/X		
336	PROMPT	392	CF 21	448	ADV	504	.END.		

EXAMPLE 3.24

(See also p. 135 in manual)

Data from Appendix I,
Tab. 9.1

* FB 24 *

RESULTS :

n : 7.
r₁₂ : 0.857
σ' : 0.116
θ' : 0.371

P : 10.000
R(HM) : 6.541
R(AM) : 6.827

P : 30.000
R(HM) : 7.966
R(AM) : 8.314

P : 45.000
R(HM) : 8.064
R(AM) : 8.416

P : 60.000
R(HM) : 8.200
R(AM) : 8.559

P : 72.000
R(HM) : 8.270
R(AM) : 8.632

P : 80.000
R(HM) : 8.305
R(AM) : 8.669

P : 122.000
R(HM) : 8.417
R(AM) : 8.785

3.25: PROGRAM DESCRIPTION FB 25

Ricker's Stock Recruitment Curves

The first of the stock-recruitment curves discussed in Ricker (1975) has the form

$$R = \alpha P e^{-\beta P} \quad \dots 1)$$

where P is the parental stock size, R the corresponding number of recruits, α (alpha) is an index of density-independent mortality and β (beta) an index of density dependent mortality.

The second form of the curve is

$$R = P e^{a(1-P/P_r)} \quad \dots 2)$$

where P_r is the replacement abundance (i.e., the point at which the replacement line cuts the stock-recruitment curve) and $a = P_r/P_m$, P_m being the parent stock size at maximum recruitment.

The fitting of the curves and the estimation of the ratio $R_{(AM)}/R_{(GM)}$ follows the method outlined in Ricker (1975, p. 282-289) which should be consulted for details and further considerations.

Operating Limits and Warnings

The geometric mean values ($R_{(GM)}$) are the most probable R for the observed P -values, not the long-term (arithmetic mean) average R obtained at a given P (Ricker 1975).

FB 25: RICKER'S STOCK RECRUITMENT CURVES

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM			* FB 25 *
1.	DISPLAY OF MENU			MENU:
1.1	CASE 1: P AND R IN DIFFERENT UNITS			P,R <DIFF. U.>: A
1.2	CASE 2: P AND R IN THE SAME UNITS			P,R <SAME U.> : B
1.3	MENU			MENU: C
1.4	} SEE			INIT: c
1.5	} GENERAL			REV. DATA: D
1.6	} INSTRUCTIONS			REV. RES.: E <PROGR. STOP>
2.	SELECT CASE 1(A) OR 2(B)		A OR B	DATA INPUT NO. OF ROWS?
2.1	ENTER NO. OF ROWS	k	R/S	1. ROW:
2.2	ENTER FOR ROW 1,2...k			P?
2.2.1	SPAWNING STOCK SIZE	P	R/S	R?
2.2.2	NUMBER OF RECRUITS	R	R/S	2. (3...k) ROW:
3.	CONTINUATION			PLEASE WAIT <RESULTS>
3.1	FOR CASE 1 (DIFFERENT UNITS)			
3.1.1	DISPLAY OF RESULTS			
3.1.1.1	COEFFICIENT OF DETERMINATION (r^2)			R^2: (x)
3.1.1.2	ALPHA			<a>: (x)
3.1.1.3	BETA			: (x)
3.1.1.4	PARENT STOCK AT MAXIMUM RECRUITMENT (P)			P<M>: (x)
3.1.1.5	MAXIMUM RECRUITMENT (R_m)			R<M>: (x) (PROGR. STOP)
	NOTE:			
	TO REVIEW RESULTS, DO		E	<RESULTS>
	TO CONTINUE PROGRAM, DO		R/S	OPTION:
3.1.2	OPTION :			CONV. OF R ? YES: 1, NO: 0
3.1.2.1	TO CONVERT THE ORIGINAL VALUES OF R IN UNITS OF P:			
	ENTER	1	R/S	ENTER:
	AND ENTER AN ESTIMATE OF P_r , E.G. THE AVER. SIZE OF THE r ,			P<R> ?
	VIRGIN PARENTAL STOCK	P_r	R/S	CONVERSION:

FB 25: RICKER'S STOCK RECRUITMENT CURVES

USER INSTRUCTIONS (cont.)

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
	(PROGRAM PERFORMS THE CONVERSION AUTOMATICALLY; IF A PRINTER IS CONNECTED ALL NEW R-VALUES ARE PRINTED OUT AND A NEW REGRESSION IS COMPUTED; FOR CONTINUATION, GO TO 3.2.1 WITHOUT PRINTER, YOU CAN LOOK AT THE NEW R-VALUES VIA THE REVIEW-ROUTINE; THEN COMPUTE THE NEW RESULTS. FOR CONTINUATION, ALSO GO TO 3.2.1)			REVIEW ? RESULTS ? <RESULTS>
3.1.2.2	NO CONVERSION; ENTER	0	R/S	* R-ESTIM. *
	USE THE ORIGINAL P/R DATA PAIRS TO OBTAIN ESTIMATES OF R FOR A GIVEN P-VALUE			ENTER: P ?
3.1.2.2.1	ENTER POPULATION SIZE (P)	P	R/S	R<GM>: (x)
	(RESULT: R(GM)-ESTIMATE:)		R/S	NEXT P ?
	REPEAT STEP 3.1.2.2.1 TO OBTAIN POINTS OF A GM CURVE.			
3.2	FOR CASE 2 (SAME UNITS)			
3.2.1	DISPLAY OF RESULTS			
3.2.1.1	COEFFICIENT OF DETERMINATION (r^2)			R^2: (x)
3.2.1.2	a (=P / P)			a : (x)
3.2.1.3	REPLACEMENT ABUNDANCE			P<R>: (x)
3.2.2	OPTION :			
3.2.2.1	TO REVIEW RESULTS, PRESS		E	<RESULTS>
3.2.2.2	TO CONTINUE THE PROGRAM, PRESS		R/S	* R-ESTIM. *
3.2.3	TO OBTAIN ESTIMATES OF R_{GM} AND R_{AM}			ENTER: P ?
	ENTER POP. SIZE (P)	P	R/S	R<GM>: (x)
	(RESULTS: R_{GM} AND R_{AM} - ESTIMATES			R<AM>: (x)
			R/S	NEXT P ?
	REPEAT STEP 3.2.3 TO OBTAIN POINTS FOR GM AND AM CURVES			

REGISTERS, STATUS, FLAGS

```
-----
PROGR. NAME:          FB 25  (Ricker's Stock-Recruitment Curves)
-----
STATUS      :          REG. (PROGR.):  201
              SIZE (MIN.)   :  (k*2)+16          SIZE (MAX.):  118
-----
FLAGS       :          5 - 10
-----
```

ASSIGNMENTS:

A: GENERAL COMMANDS

```
INITIALIZE      :  (f)c
REVIEW RESULTS  :      E
RECALL MENU     :      C
REVIEW DATA    :      D
```

B: SPECIAL COMMANDS

```
P AND R IN DIFF. UNITS:  A
P AND R IN SAME UNITS :  B
```

REGISTERS :

SUB-

PROGR.:	A	A	B	B
00 :	[u]	[u]	[u]	[u]
01 :	P<m>	P	[u]	P
02 :	R<m>	R<GM>	[u]	R<GM>
03 :	r ²		r ²	R<AM>
04 :	<BETA>		a	
05 :	<ALPHA>		P<r>	
06 :	[u]		[u]	
07 :	[u]		[u]	
08 :	[u]		[u]	
09 :	[u]		[u]	
10 :	[u]		[u]	
11 :	[u]		[u]	
12 :	[u]		[u]	
13 :	[u]		[u]	
14 :	[u]		[u]	
15 :	n		n	
16 :	P(1)		P(1)	
17 :	R(1)		R(1)	
	.		.	
	.		.	
	P(k)		P(k)	
	R(k)		R(k)	

NOTE: "k" REPRESENTS NUMBER OF CASES (= NO. OF ROWS).

Program Listing

(FB 25)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01*LBL "FB 25"		57 CF 10		113 CLA		169 PSE		225 RCL 10	
02*LBL C		58*LBL 01		114 XEQ 05		170 "YES: 1, NO: 0"		226 *	
03 CF 21		59 FIX 0		115 "HNO. ?"		171 PROMPT		227 -	
04 BEEP		60 "DATA INPUT"		116 PROMPT		172 RTN		228 RCL 15	
05 " * FB 25 *"		61 AVIEW		117 2		173*LBL 05		229 /	
06 XEQ "AC"		62 PSE		118 *		174 "F ROW "		230 E+X	
07 SF 27		63 "NO. OF ROWS ?"		119 14		175 FC? 06		231 FS? 10	
08 CF 08		64 PROMPT		120 +		176 RTN		232 GTO 08	
09 CF 09		65 STO 00		121 FIX 2		177 "F:"		233 X<> 05	
10 SREG 10		66 XEQ "U"		122 "P"		178 AVIEW		234 CHS	
11 CLRG		67 RCL 00		123 XEQ "P"		179 RTN		235 STO 04	
12*LBL C		68 3		124 1		180*LBL "K"		236 1/X	
13 "MENU :"		69 10+X		125 +		181 "PLEASE WAIT"		237 STO 01	
14 AVIEW		70 /		126 STO 07		182 AVIEW		238 RCL 05	
15 PSE		71 1		127 "R"		183 XEQ "U"		239 RCL 04	
16 PSE		72 +		128 XEQ "P"		184 CLZ		240 /	
17 "P,R<DIFF. U.>:"		73 STO 00		129 FS? 09		185*LBL "L"		241 1	
18 "F A"		74 SF 06		130 GTO 01		186 RCL IND 06		242 E+X	
19 AVIEW		75 "1."		131 "CORRECTION ?"		187 STO 07		243 /	
20 PSE		76 XEQ 05		132 XEQ 14		188 LN		244 STO 02	
21 PSE		77 PSE		133 X=0?		189 ISG 06		245 CF 05	
22 "P,R<SAME U.>: B"		78*LBL "R"		134 GTO 01		190 RCL IND 06		246 CF 07	
23 AVIEW		79 "P ?"		135 RCL 07		191 LN		247 FS? 55	
24 PSE		80 PROMPT		136 1		192 X<>Y		248 GTO 01	
25 PSE		81 "R ?"		137 -		193 -		249 BEEP	
26 "MENU : C"		82 PROMPT		138 SF 06		194 RCL 07		250*LBL "Q"	
27 AVIEW		83 ISG 00		139 "CORR. INP."		195 Z+		251 FS? 05	
28 PSE		84 GTO 01		140 AVIEW		196 ISG 06		252 SF 07	
29 "INIT.: C"		85 SF 09		141 PSE		197 GTO "L"		253 FIX 3	
30 AVIEW		86 GTO 02		142 "P ?"		198 RCL 14		254 "R+2"	
31 PSE		87*LBL 01		143 PROMPT		199 RCL 10		255 3	
32 "REV. DATA : D"		88 CLA		144 STO IND Y		200 RCL 12		256 XEQ "P"	
33 AVIEW		89 ARCL 00		145 RDN		201 *		257 "<a"	
34 PSE		90 "1."		146 1		202 RCL 15		258 5	
35 "REV. RES.: E"		91 XEQ 05		147 +		203 /		259 XEQ "T"	
36 PROMPT		92*LBL 02		148 "R ?"		204 -		260 "<b"	
37 GTO C		93 X<>Y		149 PROMPT		205 STO 05		261 4	
38*LBL E		94 STO IND 06		150 STO IND Y		206 X+2		262 XEQ "T"	
39 FS? 08		95 ISG 06		151 FC? 06		207 RCL 13		263 "P<M"	
40 GTO "0"		96 X<>Y		152*LBL 01		208 RCL 12		264 1	
41 FS? 10		97 STO IND 06		153 "MORE "		209 X+2		265 XEQ "T"	
42 GTO "2"		98 FS?C 09		154*LBL 07		210 RCL 15		266 "R<M"	
43 GTO "0"		99 GTO 01		155 "F-REVIEW?"		211 /		267 2	
44*LBL B		100 ISG 06		156 XEQ 14		212 -		268 XEQ "T"	
45 SF 10		101 GTO "R"		157 X=0?		213 /		269 FC? 07	
46 "SAME UNITS"		102*LBL 01		158 GTO D		214 RCL 11		270 STOP	
47 XEQ "AC"		103 CF 06		159 "RESULTS ?"		215 RCL 10		271 GTO 03	
48 FC?C 09		104 CLA		160 XEQ 14		216 X+2		272*LBL 01	
49 GTO 01		105 RCL 00		161 X=0?		217 RCL 15		273 XEQ "AA"	
50 CLA		106 INT		162 GTO D		218 /		274 SF 21	
51 FS? 55		107 1		163 CF 09		219 -		275 ADV	
52 GTO "K"		108 -		164 CF 06		220 ST/ 05		276 SF 13	
53 GTO 07		109 STO 00		165 GTO "K"		221 /		277 FIX 3	
54*LBL A		110 GTO 07		166*LBL 14		222 STO 03		278 3	
55 "DIFF. UNITS"		111*LBL D		167 AVIEW		223 RCL 12		279 "R+2"	
56 XEQ "AC"		112 CF 06		168 TONE 7		224 RCL 05		280 XEQ "X"	

Program Listing

(FB 25 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
281	CF 13	337	ST/ 02	393	FC? 07	449	GTO "M"	505	*
282	CLA	338	RCL 00	394	STOP	450+LBL "SW"	506	RCL 05	
283	4	339	3	395	GTO 03	451	XEQ 09	507	*
284	ACCHR	340	10tX	396+LBL 01	452	STO 02	508	RTN	
285	5	341	/	397	XEQ "AA"	453	RCL 07	509+LBL "AC"	
286	XEQ 01	342	1	398	SF 21	454	*	510	AVIEW
287	CLA	343	+	399	ADV	455	STO 03	511	PSE
288	5	344	STO 06	400	SF 13	456	GTO "W"	512	FC? 55
289	ACCHR	345	17	401	?	457+LBL 09	513	RTN	
290	4	346	STO 09	402	"R12"	458	STO 09	514	SF 21
291	XEQ 01	347+LBL "Y"	403	XEQ "X"	459	RCL 05	515	ADV	
292	1	348	RCL 02	404	CF 13	460	/	516	ADV
293	"P"	349	ST/ IND 09	405	4	461	CHS	517	SF 12
294	XEQ 02	350	FC? 55	406	"a "	462	1	518	GTO 01
295	2	351	GTO 01	407	XEQ 01	463	+	519+LBL "AA"	
296	"R"	352	SF 21	408	5	464	RCL 04	520	"RESULTS :"
297	XEQ 02	353	RCL 09	409	"P"	465	*	521	BEEP
298	CF 21	354	FIX 0	410	XEQ 02	466	E1X	522+LBL "AB"	
299	GTO 03	355	"NEW R"	411	CF 21	467	RCL 09	523	AVIEW
300+LBL 02		356	ARCL 06	412	GTO 03	468	*	524	FC? 55
301	ACA	357	"t>"	413+LBL 02	469	RTN		525	RTN
302	SF 13	358	FIX 2	414	ACA	470+LBL "T"		526	SF 21
303	"M"	359	XEQ "X"	415	SF 13	471	"t>"	527	ADV
304	ACA	360	CF 21	416	"R"	472+LBL "P"		528+LBL 01	
305	CF 13	361+LBL 01	417	ACA	473	"t : "		529	ACA
306	CLA	362	2	418	CF 13	474	ARCL IND X	530	PRBUF
307+LBL 01		363	ST+ 09	419	CLA	475	AVIEW	531	CF 12
308	"t "	364	ISC 06	420+LBL 01	476	PSE		532	CF 21
309	GTO "X"	365	GTO "Y"	421	"t "	477	PSE	533	RTN
310+LBL 03		366	GTO 0	422	GTO "X"	478	RTN	534+LBL "M"	
311	SF 05	367+LBL 08	423+LBL 03	479+LBL "X"		535	TONE 7		
312	"OPTION "	368	LN	424	SF 05	480	"t :"	536	"ENTER :"
313	AVIEW	369	STO 04	425	"* R-ESTIM. *	481	ACA	537	AVIEW
314	PSE	370	RCL 05	426	XEQ "U"	482	RCL IND X	538	PSE
315	PSE	371	/	427	0	483	ACX	539	PSE
316	"CONV. OF R ?"	372	CHS	428	STO 02	484	PRBUF	540	CLA
317	XEQ 14	373	STO 05	429	AVIEW	485	RTN	541	GTO 01
318	X*0?	374	CF 05	430+LBL "S"	486+LBL "U"		542+LBL "N"		
319	GTO 01	375	CF 07	431	RCL IND 06	487	RCL 00	543	"NEXT "
320	"* R-ESTIM. *	376	FIX 3	432	XEQ 09	488	2	544+LBL 01	
321	AVIEW	377	FS? 55	433	LOG	489	*	545	"tP"
322	PSE	378	GTO 01	434	ISC 06	490	15	546	FS? 09
323	GTO 02	379	BEEP	435	RCL IND 06	491	+	547	"t(R)"
324+LBL 01		380+LBL "Z"	436	LOG	492	3		548	"t ?"
325	SF 09	381	FS? 05	437	-	493	10tX	549	PROMPT
326+LBL 02		382	SF 07	438	X12	494	/	550	STO 01
327	GTO "M"	383	FIX 3	439	ST+ 02	495	16	551	FS? 10
328+LBL "00"		384	"R12"	440	ISC 06	496	+	552	GTO "SW"
329	STO 01	385	3	441	GTO "S"	497	STO 06	553	GTO "00"
330	XEQ "V"	386	XEQ "P"	442	RCL 02	498	RTN	554+LBL "W"	
331	STO 02	387	"a"	443	RCL 00	499+LBL "V"		555	SF 08
332	FC? 09	388	4	444	/	500	RCL 04	556	CF 05
333	GTO "W"	389	XEQ "P"	445	1.1518	501	CHS	557	CF 07
334	"CONVERSION :"	390	"P(R"	446	*	502	*	558	FIX 1
335	XEQ "AB"	391	5	447	10tX	503	E1X	559	FS? 55
336	RCL 01	392	XEQ "T"	448	STO 07	504	RCL 01	560	GTO 01

Program Listing

(FB 25 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
561	*LBL "0"								
562	FS? 05								
563	SF 07								
564	"R<GM"								
565	2								
566	XEQ "T"								
567	FC? 10								
568	GTO 03								
569	"R<AM"								
570	3								
571	XEQ "T"								
572	*LBL 03								
573	FC? 07								
574	STOP								
575	GTO 02								
576	*LBL 01								
577	XEQ 01								
578	*LBL 02								
579	SF 05								
580	GTO "N"								
581	*LBL 01								
582	SF 21								
583	ADV								
584	"P"								
585	1								
586	XEQ "X"								
587	"R<GM)"								
588	2								
589	XEQ "X"								
590	FC? 10								
591	GTO 01								
592	"R<AM)"								
593	3								
594	XEQ "X"								
595	*LBL 01								
596	CF 21								
597	.END.								

EXAMPLE 3.25

(See also p. 136 in manual)

Data from Appendix I,
Tab. 9.2

* FB 25 *

DIFF. UNITS

RESULTS :

r_{t2} : 0.694
a : 0.866
b : 0.001
P_m : 937.348
R_m : 305.516

CONVERSION

NEW R<1.> : 4,606.89
NEW R<2.> : 5,628.50
NEW R<3.> : 2,660.04
NEW R<4.> : 3,893.69
NEW R<5.> : 1,750.23
NEW R<6.> : 298.77
NEW R<7.> : 1,069.00
NEW R<8.> : 171.55

SAME UNITS

RESULTS :

r_{t2} : 0.694
a : 2.838
Pr : 2,660.000

P : 10.0
R<GM> : 169.0
R<AM> : 190.9

P : 100.0
R<GM> : 1,535.0
R<AM> : 1,733.8

P : 1,000.0
R<GM> : 5,876.5
R<AM> : 6,637.6

P : 2,000.0
R<GM> : 4,044.1
R<AM> : 4,567.9

P : 2,500.0
R<GM> : 2,965.3
R<AM> : 3,345.4

3.26: PROGRAM DESCRIPTION FB 26

Schaefer's and Fox' Models

When a fishery is in equilibrium, surplus yield can be described by a parabolic function of effort, i.e.

$$Y = af - bf^2 \quad \dots 1)$$

where a and b are constants and f is fishing effort; Maximum Sustainable Yield (MSY) and the corresponding optimum effort (f_{opt}) can be estimated from the relationships

$$MSY = a^2/4 |b| \quad \dots 2)$$

and

$$f_{opt} = a/2 |b| \quad \dots 3)$$

(Note use of absolute values of b , i.e. of $|b|$). The values of the constants a and b are generally obtained by plotting c/f on effort, a and b being the intercept and slope, respectively, of the resulting linear regression (the model used here is a GM regression; see Ricker 1975).

When $\ln(c/f)$ is plotted on f , a yield curve is obtained which has the form

$$Y = fe^a e^{-bf} \quad \dots 4)$$

with
and

$$MSY = e^{a-1}/|b| \quad \dots 5)$$

$$f_{opt} = 1/|b| \quad \dots 6)$$

and where a and b are the intercept and slope, respectively, of a GM regression of $\ln(c/f)$ on f (Schaefer 1957, Fox 1970, Ricker 1975).

Operating Limits and Warnings

These models are based on the assumption that data used refer to equilibrium effort and equilibrium yield. When this is not the case, a bias will occur whose magnitude is a function of both the life-span of the fish in question, and of the extent of the effort changes (see Gulland (1969) and manual, p. 141-143 and Table 10.2 for a method to simulate equilibrium conditions).

The results obtained here will differ slightly from those obtained using the more common AM regression.

FB 26: SCHAEFER AND FOX'S MODELS

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM			* FB 26 *
1.	DISPLAY OF MENU:			MENU
1.2	SCHAEFER MODEL			SCHAEF. M.: A
1.3	FOX MODEL			FOX MODEL : B
1.4	MENU DISPLAY			MENU : C
1.5	INITIALIZE			INIT.: c
1.6	REVIEW PRECEDING DATA INPUT			REV. INPUT: D
1.7	REVIEW PRECEDING RESULTS			REV. RES. : E <PROGR. STOP>
2.	SELECT MODEL:			
2.1	SCHAEFER MODEL		A	* SCHAEFER *
2.2	FOX MODEL		B	* FOX *
3.	DATA INPUT:			DATA INPUT:
				NO. OF ROWS ?
3.1	ENTER NO. OF ROWS	k	R/S	1. ROW:
3.2	FIRST INPUT: ENTER			CATCH ?
3.2.1	CATCH	C_1	R/S	EFFORT ?
3.2.2	EFFORT	f_1	R/S	2. (3...k) ROW: PLEASE WAIT <RESULTS>
4.	DISPLAY OF RESULTS:			
4.1	COEFFICIENT OF DETERMINATION [r^2]			R^2 : (x)
4.2	a			a : (x)
4.3	b			b : (x)
4.4	f (opt)			F opt: (x)
4.5	MSY			MSY: (x) <PROGR. STOP>

FB 26: SCHAEFER AND FOX'S MODELS

USER INSTRUCTIONS (cont.)

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
5.	TO REVIEW RESULTS, PRESS		E	<RESULTS>
6.	TO CONTINUE PROGRAM, PRESS		R/S	Y - ESTIM.: ENTER: F* ?
7.	TO CALCULATE THE YIELD FOR ANY GIVEN LEVEL OF EFFORT, ENTER	f	R/S	Y: (x) NEXT F* ?
7.1	REPEAT STEP 7. TO OBTAIN POINTS OF A YIELD CURVE			
	NOTE: TO APPLY SAME SET OF DATA TO A DIFFERENT MODEL, PRESS "A" OR "B" AND GO TO STEP 4 (RESULTS)		A/B	<NAME OF MODEL> PLEASE WAIT

REGISTERS, STATUS, FLAGS

PROGR. NAME: FB 26 (Schaefer and Fox Models)

STATUS : REG. (PROGR.): 130
SIZE (MIN.) : 022 SIZE (MAX.): -

FLAGS : 5 - 10

ASSIGNMENTS:

A: GENERAL COMMANDS

B: SPECIAL COMMANDS

INITIALIZE : (f)c
REVIEW RESULTS : E
RECALL MENU : C
REVIEW DATA : D

SCHAEFER MODEL : A
FOX MODEL : B

REGISTERS :

SUB-

PROGR.:

A

B

00 :	[u]	[u]
01 :	f<opt>	f<opt>
02 :	MSY ₂	MSY ₂
03 :	r ₂	r ₂
04 :	a	a
05 :	b	b
06 :	f	f
07 :	Y	Y
08 :	[u]	[u]
09 :	[u]	[u]
10 :	[u]	[u]
11 :	[u]	[u]
12 :	[u]	[u]
13 :	[u]	[u]
14 :	[u]	[u]
15 :	[u]	[u]
16 :	[u]	[u]
17 :	[u]	[u]
18 :	[u]	[u]
19 :	[u]	[u]
20 :	[u]	[u]
21 :	[u]	[u]

Program Listing

(FB 26)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01*LBL "FB 26"		57 PROMPT		113*LBL "Y"		169 -		225 4	
02*LBL C		58 3		114 XEQ 07		170 ST/ 05		226 XEQ "P"	
03 CF 21		59 101X		115 XEQ "W"		171 /		227 "b"	
04 BEEP		60 /		116 STO 01		172 STO 03		228 5	
05 " * FB 26 *"		61 1		117 X<>Y		173 SQRT		229 XEQ "P"	
06 XEQ "Q"		62 +		118 STO 02		174 ST/ 05		230 "F<0.>"	
07 SF 27		63 STO 00		119 ISG 00		175 RCL 12		231 1	
08 CF 06		64 GTO "Y"		120*LBL 01		176 RCL 05		232 XEQ "P"	
09 CF 09		65*LBL "R"		121 FC? 06		177 RCL 10		233 "MSY"	
10 CF 09		66 FC? 06		122 XEQ 07		178 *		234 2	
11 SREG 10		67 XEQ "W"		123 GTO "R"		179 -		235 XEQ "P"	
12 CLRG		68 X<> 01		124*LBL 14		180 RCL 15		236 FC? 07	
13*LBL C		69 X<>Y		125 AVIEW		181 /		237 STOP	
14 "MENU :"		70 X<> 02		126 TONE 7		182 STO 04		238 GTO 03	
15 AVIEW		71 X<>Y		127 PSE		183 RCL 05		239*LBL 01	
16 PSE		72 STO 00		128 "YES: 1. NO: 0"		184 CHS		240 XEQ "S"	
17 PSE		73 /		129 PROMPT		185 1/X		241 SF 21	
18 "SCHAEF. M. A"		74 STO 09		130 RTN		186 FS? 10		242 ADV	
19 AVIEW		75 FS? 06		131*LBL 07		187 GTO 01		243 SF 13	
20 PSE		76 GTO 02		132 FIX 0		188 *		244 3	
21 PSE		77 ISG 00		133 CLA		189 2		245 "R+2"	
22 "FOX MODEL : B"		78 GTO 01		134 ARCL 00		190 /		246 XEQ "X"	
23 AVIEW		79 SF 09		135 "L. ROW :"		191*LBL 01		247 4	
24 PSE		80 GTO 02		136 GTO 01		192 STO 01		248 "a"	
25 PSE		81*LBL 01		137*LBL 05		193 RCL 05		249 XEQ 01	
26 "MENU : C"		82 XEQ 07		138 "L INPUT :"		194 CHS		250 5	
27 AVIEW		83*LBL 02		139*LBL 01		195 1/X		251 "b"	
28 PSE		84 SREG 10		140 AVIEW		196 RCL 04		252 XEQ 01	
29 "INIT.: C"		85 RCL 09		141 PSE		197 FS? 10		253 ADV	
30 AVIEW		86 RCL 00		142 RTN		198 GTO 01		254 "F<OPT>"	
31 PSE		87 2+		143*LBL 04		199 X+2		255 1	
32 "REV. INPUT : D"		88 SREG 16		144 "PLEASE WAIT"		200 4		256 XEQ "P"	
33 AVIEW		89 X<>Y		145 AVIEW		201 /		257 CF 13	
34 PSE		90 LN		146 FS? 10		202 GTO 02		258 "MSY"	
35 "REV. RES.: E"		91 RCL 00		147 XEQ "L"		203*LBL 01		259 2	
36 PROMPT		92 2+		148 RCL 14		204 1		260 XEQ "P"	
37 GTO C		93 FS? 06		149 RCL 10		205 -		261 CF 21	
38*LBL E		94 GTO 04		150 RCL 12		206 E1X		262 GTO 03	
39 FS? 00		95 FC? 09		151 *		207*LBL 02		263*LBL 01	
40 GTO "0"		96 GTO "R"		152 RCL 15		208 *		264 "L"	
41 GTO "Z"		97 SF 06		153 /		209 STO 02		265 GTO "X"	
42*LBL B		98*LBL D		154 -		210 FS? 10		266*LBL 03	
43 SF 10		99 "LAST"		155 STO 05		211 XEQ "L"		267 SF 05	
44 "** FOX **"		100 XEQ 05		156 X+2		212 CF 05		268 TONE 7	
45 XEQ "Q"		101 FIX 3		157 RCL 13		213 CF 07		269 "Y-ESTIM.:"	
46 GTO 01		102 2		158 RCL 12		214 FIX 3		270 XEQ "T"	
47*LBL A		103 "C"		159 X+2		215 FS? 55		271 PSE	
48 CF 10		104 XEQ "P"		160 RCL 15		216 GTO 01		272 "ENTER :"	
49 "** SCHAEFER **"		105 1		161 /		217 BEEP		273 AVIEW	
50 XEQ "Q"		106 "F*"		162 -		218*LBL "Z"		274 PSE	
51*LBL 01		107 XEQ "R"		163 /		219 FS? 05		275 PSE	
52 FS? 09		108 "CORRECTION ?"		164 RCL 11		220 SF 07		276 CLA	
53 GTO 04		109 XEQ 14		165 RCL 10		221 "R+2"		277 GTO 01	
54 "DATA"		110 X=0?		166 X+2		222 3		278*LBL "H"	
55 XEQ 05		111 GTO 01		167 RCL 15		223 XEQ "P"		279 "NEXT"	
56 "NO. OF ROWS ?"		112 DSE 00		168 /		224 "a"		280*LBL 01	

Program Listing

(FB 26 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
281	"FF* ?"	337	LBL "X"						
282	PROMPT	338	"F : "						
283	SF 08	339	ACA						
284	FIX 3	340	RCL IND X						
285	STO 06	341	ACX						
286	RCL 05	342	PRBUF						
287	*	343	RTN						
288	RCL 04	344	LBL "Q"						
289	+	345	AVIEW						
290	FS? 10	346	PSE						
291	E+X	347	FC? 55						
292	RCL 06	348	RTN						
293	*	349	SF 21						
294	STO 07	350	ADV						
295	FS? 55	351	ADV						
296	GTO 01	352	SF 12						
297	LBL "O"	353	GTO 01						
298	"Y"	354	LBL "S"						
299	7	355	"RESULTS :"						
300	XEQ "P"	356	BEEP						
301	PSE	357	LBL "T"						
302	GTO "N"	358	AVIEW						
303	LBL 01	359	FC? 55						
304	SF 21	360	RTN						
305	ADV	361	SF 21						
306	SF 13	362	ADV						
307	"F"	363	LBL 01						
308	6	364	ACA						
309	XEQ "X"	365	PRBUF						
310	CF 13	366	CF 12						
311	"Y"	367	CF 21						
312	7	368	RTN						
313	XEQ "X"	369	LBL "W"						
314	CF 21	370	TONE 7						
315	GTO "N"	371	"CATCH ?"						
316	LBL "L"	372	PROMPT						
317	10	373	"EFFORT ?"						
318	STO 09	374	PROMPT						
319	16.021	375	.END.						
320	STO 08								
321	LBL "M"								
322	RCL IND 08								
323	X(> IND 09								
324	STO IND 08								
325	ISG 09								
326	STO X								
327	ISG 08								
328	GTO "M"								
329	RTN								
330	LBL "P"								
331	"F : "								
332	ARCL IND X								
333	AVIEW								
334	PSE								
335	PSE								
336	RTN								

EXAMPLE 3.26

(See also p. 148 & 150 in manual)

Data from Appendix I,
Tab. 10.1

Data from Appendix I,
Tab. 10.3

* FB 26 *

* FB 26 *

* SCHAEFER *

* FOX *

RESULTS :

RESULTS :

r² : 0.874
a : 2.285
b : -0.038

r² : 0.966
a : -2.027
b : -0.001

f(opt) : 29.879
MSY : 34.133

f(opt) : 1,251.987
MSY : 60.658

Y-ESTIM.:

Y-ESTIM.:

f : 10.000
Y : 19.024

f : 50.000
Y : 6.327

f : 20.000
Y : 30.402

f : 100.000
Y : 12.159

f : 30.000
Y : 34.133

f : 200.000
Y : 22.451

f : 40.000
Y : 30.217

f : 400.000
Y : 36.272

f : 50.000
Y : 18.655

f : 800.000
Y : 55.611

f : 59.000
Y : 1.711

f : 1,200.000
Y : 60.604

f : 1,600.000
Y : 58.706

f : 2,000.000
Y : 53.314

f : 2,500.000
Y : 44.700

f : 3,000.000
Y : 35.979

3.27: PROGRAM DESCRIPTION FB 27

Schnute's Yield Model

Schnute (1977) demonstrated that, given a time series of catch and effort data, several fisheries-related parameters can be estimated from the multiple regression

$$\ln \frac{U_i}{U_{i-1}} = r_m - q \cdot \frac{f_i + f_{i-1}}{2} - \frac{r_m}{qB_{\infty}} \cdot \frac{U_i + U_{i-1}}{2} \quad \dots 1)$$

where U_i is the mean catch per effort (c/f) in a given year (i). Once r_m , q and the term r_m/qB_{∞} have been estimated (as intercept and slopes of the regression, respectively), the catch can be estimated for any level of effort (including f_{opt}) from

$$Y_i = qB_{\infty} f_i (1 - (q/r_m)f_i) \quad \dots 2)$$

while f_{opt} can be estimated from

$$f_{opt} = r_m/2q \quad \dots 3)$$

Schnute (1977) gives a number of other equations pertaining to this model; the original paper should be consulted for these.

Operating Limits and Warnings

- 1) See Schnute (1977) for limitations of the model.
- 2) Note that R^2 for the multiple regression in (1) are usually very low.

FB 27: SCHNUTE'S YIELD MODEL

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM			* FB 27 *
1.	DISPLAY OF MENU:			MENU:
1.1	DATA INPUT			DATA INP.: A
1.2	}			MENU : C
1.3	} SEE GENERAL			INIT. : c
1.4	} INSTRUCTIONS			REV. INPUT: D
1.5	}			REV. RES. : E
				<PROGR. STOP>
2.	TO START DATA INPUT, PRESS		A	* SCHNUTE *
				DATA INPUT:
				NO. OF ROWS ?
2.1	ENTER NO. OF ROWS	k	R/S	1. ROW:
2.2	ENTER FOR ROW 1,2...k			CATCH ?
2.2.1	CATCH ^{a)}	C ₁	R/S	EFFORT ?
2.2.2	EFFORT	f ₁	R/S	2. (3...k) ROW:
				PLEASE WAIT
				<RESULTS>
3.	DISPLAY OF RESULTS:			
3.1	MULTIPLE COEFFICIENT OF DETERMINATION (R ²)			R ² : (x)
3.2	a		R/S	a : (x)
3.3	b ₁		R/S	b<1>: (x)
3.4	b ₂		R/S	b<2>: (x)
3.5	r _m		R/S	R<M>: (x)
3.6	q		R/S	Q : (x)
3.7	ENVIRONMENTAL CARRYING CAPACITY (B _∞)		R/S	B<00>: (x)
3.8	LEVEL OF EFFORT GENERATING MSY (f _{opt} = F<0.>)		R/S	F<0.> : (x)
3.9	MAXIMUM SUSTAINABLE YIELD (MSY)		R/S	MSY : (x)

a) WARNING: BE SURE TO ENTER THE CATCH ONLY AFTER "CATCH ?" HAS BEEN DISPLAYED. FOR YOUR CONVENIENCE, THE DISPLAY OF THE SIGN IS ACCOMPANIED BY A "BEEP" SOUND.

FB 27: SCHNUTE'S YIELD MODEL

USER INSTRUCTIONS (cont.)

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
4.	FOR A FAST REVIEW OF RESULTS, PRESS		E	<RESULTS>
5.	TO CONTINUE PROGRAM, PRESS		R/S	Y-ESTIM.: ENTER: F* ?
6.	TO CALCULATE THE YIELD FOR ANY GIVEN LEVEL OF EFFORT, ENTER	f	R/S	Y: (x) NEXT F* ?
6.1	REPEAT STEP 6 TO OBTAIN THE POINTS OF A YIELD CURVE			

REGISTERS, STATUS, FLAGS

PROGR. NAME: FB 27 (Schnute's Yield Model)

STATUS : REG. (PROGR.): 147
 SIZE (MIN.) : 020 SIZE (MAX.): -

FLAGS : 5, 7 - 10

ASSIGNMENTS:

A: GENERAL COMMANDS

B: SPECIAL COMMANDS

INITIALIZE : (f)c
REVIEW RESULTS : E
RECALL MENU : C
REVIEW DATA : D

DATA INPUT : A

REGISTERS :

SUB-
PROGR.: A A

00 : [u] [u]
01 : f<opt> f
02 : MSY₂ Y
03 : R²
04 : a : r<m>
05 : b<1>
06 : b<2>
07 : q
08 : B<∞>
09 : -
10 : [u]
11 : [u]
12 : [u]
13 : [u]
14 : {u}
15 : [u]
16 : [u]
17 : [u]
18 : [u]
19 : [u]

Program Listing

(FB 27)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01	LBL "FB 27"	57	LBL "R"	113	FS? 10	169	RCL 11	225	CHS
02	LBL c	58	FC? 10	114	GTO 04	170	*	226	STO 07
03	CF 21	59	XEQ "W"	115	FC? 09	171	RCL 10	227	RCL 18
04	BEEP	60	X<> 01	116	GTO "R"	172	X↑2	228	RCL 06
05	" * FB 27 *"	61	X<>Y	117	SF 10	173	-	229	RCL 12
06	XEQ "0"	62	X<> 02	118	LBL D	174	STO 07	230	*
07	SF 27	63	X<>Y	119	"LAST"	175	RCL 15	231	-
08	CF 05	64	STO 05	120	XEQ 05	176	RCL 17	232	RCL 05
09	CF 07	65	/	121	FIX 3	177	*	233	RCL 10
10	CF 08	66	STO 06	122	SF 08	178	RCL 12	234	*
11	CF 09	67	FS? 10	123	2	179	RCL 18	235	-
12	CF 10	68	GTO 02	124	"C"	180	*	236	RCL 15
13	SREG 10	69	ISG 00	125	XEQ "P"	181	-	237	/
14	CLRG	70	GTO 01	126	1	182	*	238	STO 04
15	LBL C	71	SF 09	127	"F*"	183	STO 06	239	RCL 18
16	"MENU :"	72	GTO 02	128	XEQ "P"	184	RCL 15	240	*
17	AVIEW	73	LBL 01	129	CF 08	185	RCL 14	241	RCL 05
18	PSE	74	XEQ 07	130	"CORRECTION ?"	186	*	242	RCL 16
19	PSE	75	LBL 02	131	XEQ 14	187	RCL 10	243	*
20	"DATA INP.: A"	76	FS?C 07	132	X=0?	188	RCL 12	244	+
21	AVIEW	77	GTO 01	133	GTO 01	189	*	245	RCL 06
22	PSE	78	RCL 06	134	PSE 00	190	-	246	RCL 17
23	PSE	79	RCL 04	135	LBL "Y"	191	STO 04	247	*
24	"MENU : C"	80	/	136	XEQ 07	192	RCL 15	248	+
25	AVIEW	81	LN	137	XEQ "W"	193	RCL 16	249	RCL 18
26	PSE	82	STO 07	138	STO 01	194	*	250	X↑2
27	"INIT.: c"	83	RCL 06	139	X<>Y	195	RCL 10	251	RCL 15
28	AVIEW	84	RCL 04	140	STO 02	196	RCL 18	252	/
29	PSE	85	+	141	ISG 00	197	*	253	-
30	"REV. INPUT : D"	86	2	142	LBL 01	198	-	254	RCL 19
31	AVIEW	87	/	143	FC? 10	199	STO 05	255	RCL 18
32	PSE	88	STO 09	144	XEQ 07	200	*	256	X↑2
33	"REV. RES.: E"	89	RCL 05	145	GTO "R"	201	RCL 06	257	RCL 15
34	PROMPT	90	RCL 03	146	LBL 14	202	X<>Y	258	/
35	GTO A	91	+	147	AVIEW	203	-	259	-
36	LBL E	92	2	148	TONE 7	204	RCL 07	260	/
37	FS? 08	93	/	149	PSE	205	RCL 15	261	STO 03
38	GTO "0"	94	STO 08	150	"YES: 1, NO: 0"	206	RCL 13	262	RCL 06
39	SF 07	95	2+	151	PROMPT	207	*	263	RCL 05
40	SF 08	96	X<>Y	152	RTN	208	RCL 12	264	*
41	GTO "2"	97	RCL 08	153	LBL 07	209	X↑2	265	RCL 04
42	LBL A	98	RCL 07	154	FIX 0	210	-	266	/
43	"* SCHNUTE *"	99	ST* Y	155	CLA	211	*	267	1/X
44	XEQ "0"	100	ST* Z	156	ARCL 00	212	RCL 04	268	STO 08
45	"DATA"	101	ST+ 18	157	"F. ROW :"	213	X↑2	269	RCL 04
46	XEQ 05	102	X↑2	158	GTO 01	214	-	270	RCL 05
47	"NO. OF ROWS ?"	103	ST+ 19	159	LBL 05	215	/	271	CHS
48	PROMPT	104	RDN	160	"F INPUT :"	216	STO 06	272	/
49	3	105	ST+ 16	161	LBL 01	217	RCL 05	273	2
50	10↑X	106	X<>Y	162	AVIEW	218	RCL 04	274	/
51	/	107	ST+ 17	163	PSE	219	RCL 06	275	STO 01
52	1	108	LBL 01	164	RTN	220	*	276	XEQ 10
53	+	109	RCL 06	165	LBL 04	221	-	277	FIX 3
54	STO 00	110	STO 04	166	"PLEASE WAIT"	222	RCL 07	278	FS? 55
55	SF 07	111	RCL 05	167	AVIEW	223	/	279	GTO 02
56	GTO "Y"	112	STO 03	168	RCL 15	224	STO 05	280	BEEP

Program Listing

(FB 27 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
281	*LBL "Z"	337	XEQ 04	393	*	449	*LBL "S"		
282	FS? 05	338	7	394	RCL 05	450	*RESULTS :		
283	SF 07	339	"0"	395	*	451	BEEP		
284	*R12"	340	XEQ 01	396	CHS	452	*LBL "T"		
285	3	341	CF 13	397	RCL 01	453	AVIEW		
286	XEQ 01	342	8	398	*	454	FC? 55		
287	"a"	343	"B<00>"	399	STO 02	455	RTN		
288	4	344	XEQ 05	400	FC? 00	456	SF 21		
289	XEQ 01	345	SF 13	401	RTN	457	ADV		
290	"b<1>"	346	"F<OPT>"	402	FS? 55	458	*LBL 01		
291	5	347	1 "	403	GTO 01	459	ACA		
292	XEQ 01	348	XEQ "P"	404	*LBL "O"	460	PRBUF		
293	"b<2>"	349	CF 13	405	"Y"	461	CF 12		
294	6	350	"MSY"	406	2	462	CF 21		
295	XEQ 01	351	2	407	XEQ "P:	463	RTN		
296	"R<M>"	352	XEQ 02	408	PSE	464	*LBL "W"		
297	4	353	CF 21	409	GTO "N"	465	TONE 7		
298	XEQ 01	354	GTO 03	410	*LBL 01	466	"CATCH ?"		
299	"Q"	355	*LBL 01	411	SF 21	467	PROMPT		
300	7	356	"H "	412	ADV	468	"EFFORT ?"		
301	XEQ 01	357	*LBL 02	413	SF 13	469	PROMPT		
302	"B<00>"	358	"H "	414	"F"	470	.END.		
303	8	359	*LBL 04	415	1				
304	XEQ 01	360	"H "	416	XEQ "X"				
305	"F<0.>"	361	*LBL 05	417	CF 13				
306	1	362	"H "	418	"Y"				
307	XEQ 01	363	GTO "P"	419	2				
308	"MSY"	364	*LBL 03	420	XEQ "X"				
309	2	365	SF 05	421	CF 21				
310	XEQ 01	366	TONE 7	422	GTO "N"				
311	GTO 03	367	"Y-ESTIM.:"	423	*LBL "P"				
312	*LBL 01	368	XEQ "T"	424	"H : "				
313	XEQ "P"	369	PSE	425	ARCL IND X				
314	FC? 07	370	"ENTER :"	426	AVIEW				
315	STOP	371	AVIEW	427	FC? 00				
316	RTN	372	PSE	428	RTN				
317	*LBL 02	373	PSE	429	PSE				
318	XEQ "S"	374	CLA	430	PSE				
319	SF 21	375	CF 08	431	RTN				
320	ADV	376	GTO 01	432	*LBL "X"				
321	3	377	*LBL "N"	433	"H : "				
322	*R12 "	378	"NEXT "	434	ACA				
323	XEQ "X"	379	*LBL 01	435	RCL IND X				
324	4	380	"HF* ?"	436	ACX				
325	"a "	381	PROMPT	437	PRBUF				
326	XEQ "X"	382	SF 08	438	RTN				
327	5	383	FIX 3	439	*LBL "Q" "				
328	"b<1>"	384	*LBL 10	440	AVIEW				
329	XEQ "X"	385	STO 01	441	PSE				
330	"b<2>"	386	RCL 05	442	FC? 55				
331	6	387	*	443	RTN				
332	XEQ "X"	388	RCL 04	444	SF 21				
333	ADV	389	/	445	ADV				
334	SF 13	390	1	446	ADV				
335	4	391	+	447	SF 12				
336	"R<M>"	392	RCL 08	448	GTO 01				

EXAMPLE 3.27

(See also p. 149 in manual)

Data from Appendix I,
Tab. 10.2

* FB 27 *

* SCHNUTE *

RESULTS :

R12 : 0.006

a : 0.268

b(1) : -0.001

b(2) : -6.359

r(h) : 0.268

q : 0.001

B(00) : 70.389

f(opt) : 223.558

MSY : 4.712

Y-ESTIM.

f : 50.000

Y : 1.072

f : 100.000

Y : 3.273

f : 150.000

Y : 4.202

f : 200.000

Y : 4.660

f : 250.000

Y : 4.646

f : 300.000

Y : 4.161

f : 350.000

Y : 3.205

3.28: PROGRAM DESCRIPTION FB 28

Csirke and Caddy's Model

This program fits catch data as a parabolic function of contemporary total mortality, or

$$Y = a + b_1 Z + b_2 Z^2 \quad \dots 1)$$

where Y is the annual catch from a given fishery and Z the total mortality of the fish in that fishery.

Once a, b and c have been estimated, various parameters for the fish stock in question can be estimated, i.e.

$$M = (-b_1 + \sqrt{b_1^2 - 4ab_2})/2b_2 \quad \dots 2)$$

$$Z_{opt} = -b_1/2b_2 \quad \dots 3)$$

$$F_{opt} = - (b_1/2b_2) - M \quad \dots 4)$$

$$MSY = a - (b_1^2/4b_2) \quad \dots 5)$$

$$B_{\infty} = \sqrt{-4b_2 \text{ MSY}} \quad \dots 6)$$

$$r_m = -B_{\infty}/b_2 \quad \dots 7)$$

This model, which was proposed by Csirke and Caddy (1983) may at times generate completely erroneous parameter values (e.g., negative values of M). It should therefore be used in conjunction with other models, whenever possible.

The routine used to fit equation 1) is adapted from the HP 67/97 Stat. Pac. (ST1-13A).

If values of Z are not available, the model can be used with values of Z/K. In this case, values of M/K, $(Z/K)_{opt}$, MSY and $(F/K)_{opt}$, will be estimated by equations (2), (3), (5) and (4), respectively (B_{∞} and r_m on the other hand, cannot be estimated when only Z/K values are available). When the Z (or Z/K) values used in this model have been obtained from mean lengths, i.e. via $Z = K(L_{\infty} - L)/(L - L')$ (see manual, Chapter 5) the mean length corresponding to any value of Z (or Z/K) can be obtained from an equation derived by J. Hoenig (pers. comm.), referring here to Z_{opt} , i.e.

$$L_{opt} = \frac{L_{\infty} + (Z_{opt} \cdot L'/K)}{(Z_{opt}/K) + 1} \quad \dots 8)$$

Operating Limits and Warnings

The results given by this model should be used with caution in cases where the estimate of M differ widely from expected values; also, the multiple correlation coefficient (R) should be significant. Consult original description of this model and the manual for further details.

FB 28: CSIRKE AND CADDY'S MODEL

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM			* FB 28 *
1.	DISPLAY OF MENU:			MENU:
1.1	DATA INPUT			DATA INP.: A
1.2	{			MENU : C
1.3	{ SEE GENERAL			INIT. : c
1.4	{ INSTRUCTIONS			REV. INP.: D
1.5	{			REV. RES.: E
2.	TO START DATA INPUT, PRESS		A	CSIRKE+CADDY
2.1	ENTER NO. OF ROWS	k	R/S	NO. OF ROWS ?
				INP. MORTAL.:
				SELECT:
				Z: 1, Z/K: 2
2.2	INDICATE WHETHER MORTALITY IS EXPRESSED IN UNITS OF Z("1") OR Z/K("2")	1 OR 2	R/S	1. ROW:
3.	ENTER FOR ROW 1,2 .. k:			CATCH ?
3.1	CATCH	C	R/S	Z(/K) ?
3.2	TOTAL MORTALITY	Z OR Z/K	R/S	2. (3...k)ROW:
				:
				PLEASE WAIT
4.	DISPLAY OF RESULTS			(RESULTS)
4.1	MULTIPLE COEFFICIENT OF DETERMINATION			R^2: (x)
4.2	a		R/S	a : (x)
4.3	b ₁		R/S	b<1>: (x)
4.4	b ₂		R/S	b<2>: (x)
4.5	PARTIAL CORREL. COEFF. C <u>VS</u> Z OR Z/K		R/S	R<Y1.2>: (x)
4.6	PARTIAL CORREL. COEFF. C <u>VS</u> Z ² OR (Z/K) ²		R/S	R<Y2.1>: (x)

FB 28: CSIRKE AND CADDY'S MODEL

USER INSTRUCTIONS (cont.)

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
5.	FOR			
	<u>INPUT: Z</u> <u>INPUT: Z/K</u>			
5.1	M	M/K	R/S	M(K): (x)
5.2	Z	Z /K		Z<opt>(/K): (x)
5.3	F ^{opt}	F ^{opt} /K		F<opt>(/K): (x)
5.4	MSY	MSY		MSY: (x)
5.5	B	NOT COMPUTED		B<00>: (x)
5.6	r [∞] _m	NOT COMPUTED		R<M>: (x)
6.	OPTION:			
6.1	REVIEW OF RESULTS		E	<RESULTS>
6.2	Y-ESTIMATES FROM Z		R/S	Y-ESTIM.:
7.	TO OBTAIN YIELD ESTIMATES			Y-ESTIM.:
	ENTER:			ENTER
				Z(/K) ?
7.1	Z (OR Z/K)	Z OR Z/K	R/S	Y: (x)
7.2	OUTPUT MEAN ANNUAL YIELD			NEXT Z (/K)
7.3	REPEAT STEP 7.1, TO OBTAIN POINTS FOR PARABOLA			

REGISTERS, STATUS, FLAGS

PROGR. NAME: FB 28 (Csirke and Caddy's Model)

STATUS : REG. (PROGR.): 184
SIZE (MIN.) : 020 SIZE (MAX.): -

FLAGS : 6 - 8

ASSIGNMENTS:

A: GENERAL COMMANDS

B: SPECIAL COMMANDS

INITIALIZE : (f)c
REVIEW RESULTS : E
RECALL MENU : C
REVIEW DATA : D

DATA INPUT : A

REGISTERS :

SUB-
PROGR.: A

00 : -
01 : a
02 : r<y1.2>
03 : r<y2.1>
04 : Z
05 : Y
06 : [u]
07 : R²
08 : b<1>
09 : b<2>
10 : M
11 : Z<opt>
12 : MSY
13 : B< ∞ >
14 : r<m>
15 : F<opt>
16 : [u]
17 : [u]
18 : [u]
19 : [u]

Program Listing

(FB 28)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01	LBL "FB 28"	57	STO 09	113	SF 08	169	STO 02	225	RCL 04
02	LBL C	58	"INP. MORTAL.:"	114	:	170	STO 01	226	RCL 02
03	CF 21	59	AVIEW	115	"C"	171	STO 09	227	RCL 03
04	BEEP	60	PSE	116	XEQ "P"	172	RCL 13	228	*
05	" * FB 28 *"	61	PSE	117	PSE	173	RCL 12	229	SORT
06	XEQ "G"	62	"SELECT.:"	118	2	174	XEQ 03	230	/
07	SF 27	63	AVIEW	119	"Z"	175	STO 03	231	STO 04
08	10	64	PSE	120	XEQ "W"	176	ST* 01	232	RCL 05
09	LBL "M"	65	"Z : 1, Z/K : 2"	121	XEQ "P"	177	STO 08	233	RCL 01
10	CF IND X	66	PROMPT	122	PSE	178	RCL 18	234	RCL 02
11	DSE X	67	SF IND X	123	CF 08	179	RCL 10	235	*
12	GTO "M"	68	GTO "Y"	124	"CORRECTION ?"	180	RCL 16	236	SORT
13	CF 08	69	LBL "R"	125	XEQ 14	181	*	237	/
14	CLRG	70	FC? 06	126	X=0?	182	XEQ 04	238	STO 05
15	SREG 10	71	XEQ 10	127	GTO 01	183	STO 05	239	RCL 06
16	LBL C	72	X<> 02	128	DSE 09	184	ST* 08	240	RCL 01
17	"MENU.:"	73	STO 04	129	LBL "Y"	185	RCL 19	241	RCL 03
18	AVIEW	74	X+2	130	XEQ 07	186	RCL 12	242	*
19	PSE	75	STO 05	131	XEQ 10	187	RCL 16	243	SORT
20	"DATA INP.: A"	76	X<>Y	132	STO 02	188	*	244	/
21	AVIEW	77	X<> 01	133	X<>Y	189	XEQ 04	245	STO 06
22	PSE	78	STO 06	134	STO 01	190	STO 06	246	RCL 04
23	PSE	79	FS? 06	135	ISG 09	191	ST* 09	247	*
24	"MENU : C"	80	GTO 02	136	LBL 01	192	RCL 14	248	-
25	AVIEW	81	ISG 09	137	FC? 06	193	RCL 10	249	1
26	PSE	82	GTO 01	138	XEQ 07	194	RCL 12	250	RCL 04
27	"INIT.: c"	83	SF 09	139	GTO "R"	195	*	251	X+2
28	AVIEW	84	GTO 02	140	LBL 10	196	XEQ 04	252	-
29	PSE	85	LBL 01	141	TONE 7	197	STO 04	253	1
30	"REV. INP.: D"	86	XEQ 07	142	"CATCH ?"	198	X+2	254	RCL 06
31	AVIEW	87	LBL 02	143	PROMPT	199	ST- 01	255	X+2
32	PSE	88	RCL 05	144	"Z"	200	RCL 04	256	-
33	PSE	89	RCL 04	145	XEQ "W"	201	RCL 05	257	*
34	"REV. RES.: E"	90	Σ+	146	"F ?"	202	*	258	SORT
35	PROMPT	91	RCL 06	147	PROMPT	203	ST- 09	259	/
36	GTO C	92	ST+ 16	148	RTN	204	RCL 01	260	STO 02
37	LBL E	93	X+2	149	LBL 14	205	ST/ 09	261	RCL 06
38	FS? 08	94	ST+ 17	150	AVIEW	206	RCL 04	262	RCL 04
39	GTO "O"	95	RCL 06	151	TONE 7	207	RCL 06	263	RCL 05
40	SF 07	96	RCL 04	152	PSE	208	*	264	*
41	SF 08	97	*	153	"YES: 1, NO: 0"	209	ST- 08	265	-
42	GTO "Z"	98	ST+ 18	154	PROMPT	210	RCL 01	266	1
43	LBL A	99	RCL 06	155	RTN	211	ST/ 08	267	RCL 04
44	"CSIRKE+CADDY"	100	RCL 05	156	LBL 07	212	RCL 08	268	X+2
45	XEQ "Q"	101	*	157	FIX 0	213	RCL 05	269	-
46	"DATA INP.: "	102	ST+ 19	158	CLA	214	*	270	1
47	AVIEW	103	FS? 06	159	ARCL 09	215	RCL 09	271	RCL 05
48	PSE	104	GTO 04	160	"F. ROW.:"	216	RCL 06	272	X+2
49	PSE	105	FC? 09	161	AVIEW	217	*	273	-
50	"NO. OF ROWS ?"	106	GTO "R"	162	RTN	218	+	274	*
51	PROMPT	107	SF 06	163	LBL 04	219	RCL 17	275	SORT
52	3	108	LBL D	164	"PLEASE WAIT"	220	RCL 16	276	/
53	10+X	109	FIX 2	165	AVIEW	221	XEQ 03	277	STO 03
54	/	110	"LAST INPUT.:"	166	RCL 11	222	STO 01	278	RCL 16
55	1	111	AVIEW	167	RCL 10	223	/	279	RCL 15
56	+	112	PSE	168	XEQ 03	224	STO 07	280	/

Program Listing

(FB 28 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
281	RCL 08	337	GTO 02	393	XEQ "S"	449	XEQ 03	505	XEQ "W"
282	RCL 10	338	BEEP	394	SF 21	450	CF 13	506	5
283	*	339	LBL "Z"	395	ADV	451	GTO 06	507	XEQ "X"
284	XEQ 04	340	"R12"	396	7	452	LBL 01	508	"Y"
285	RCL 09	341	7	397	"R12"	453	"I"	509	FS? 02
286	RCL 12	342	XEQ 01	398	XEQ "X"	454	LBL 02	510	"I"
287	*	343	"a"	399	SF 13	455	"I"	511	6
288	XEQ 04	344	1	400	1	456	LBL 03	512	XEQ "X"
289	STO 01	345	XEQ 01	401	"a"	457	"I"	513	CF 21
290	GTO 06	346	"b(1)"	402	XEQ "X"	458	GTO "X"	514	GTO "W"
291	LBL 03	347	8	403	8	459	LBL 06	515	LBL "P"
292	X12	348	XEQ 01	404	"b(1)"	460	CF 21	516	"I"
293	LBL 04	349	"b(2)"	405	XEQ "X"	461	SF 07	517	ARCL IND X
294	RCL 15	350	9	406	"b(2)"	462	TONE 7	518	AVIEW
295	/	351	XEQ 01	407	9	463	"Y-ESTIM.:"	519	FC? 08
296	-	352	"R(Y1.2)"	408	XEQ "X"	464	XEQ "T"	520	RTN
297	RTN	353	2	409	ADV	465	PSE	521	PSE
298	LBL 06	354	XEQ 01	410	2	466	"ENTER :"	522	PSE
299	RCL 08	355	"R(Y2.1)"	411	"R(Y1.2)"	467	AVIEW	523	RTN
300	X12	356	3	412	XEQ "P"	468	PSE	524	LBL "X"
301	STO 12	357	XEQ 01	413	3	469	PSE	525	"I"
302	RCL 09	358	"M"	414	"R(Y2.1)"	470	CLA	526	ACA
303	4	359	10	415	XEQ "P"	471	CF 08	527	RCL IND X
304	*	360	XEQ 03	416	CF 13	472	GTO 01	528	ACX
305	CHS	361	"Z(OPT)"	417	ADV	473	LBL "N"	529	PRBUF
306	STO 13	362	11	418	ADV	474	"NEXT"	530	RTN
307	ST/ 12	363	XEQ 03	419	CF 21	475	LBL 01	531	LBL "0"
308	RCL 01	364	"F(OPT)"	420	"PARAMETERS :"	476	"I2"	532	AVIEW
309	ST+ 12	365	15	421	XEQ "T"	477	XEQ "W"	533	PSE
310	*	366	XEQ 03	422	SF 21	478	"I ?"	534	FC? 55
311	+	367	"MSY"	423	ADV	479	PROMPT	535	RTN
312	SORT	368	12	424	10	480	SF 08	536	SF 21
313	RCL 08	369	XEQ 03	425	"N"	481	FIX 3	537	ADV
314	CHS	370	FS? 02	426	XEQ "W"	482	STO 05	538	ADV
315	STO 11	371	GTO 06	427	XEQ 01	483	X12	539	SF 12
316	STO 15	372	FS? 02	428	11	484	RCL 09	540	GTO 01
317	+	373	GTO 06	429	"Z (OPT)"	485	*	541	LBL "S"
318	2	374	"B(00)"	430	XEQ "W"	486	RCL 05	542	"RESULTS :"
319	RCL 09	375	13	431	XEQ "X"	487	RCL 08	543	BEEP
320	*	376	XEQ 01	432	15	488	*	544	LBL "T"
321	ST/ 11	377	"R(N)"	433	"F (OPT)"	489	+	545	AVIEW
322	ST/ 15	378	14	434	XEQ "W"	490	RCL 01	546	FC? 55
323	/	379	XEQ 01	435	XEQ "X"	491	+	547	RTN
324	STO 10	380	GTO 06	436	12	492	STO 06	548	SF 21
325	ST- 15	381	LBL 03	437	"MSY"	493	FS? 55	549	ADV
326	RCL 12	382	XEQ "W"	438	FS? 02	494	GTO 01	550	LBL 01
327	RCL 13	383	LBL 01	439	"I"	495	LBL "0"	551	ACA
328	*	384	XEQ "P"	440	XEQ 02	496	"Y"	552	PRBUF
329	SORT	385	FS? 07	441	FS? 02	497	6	553	CF 12
330	STO 13	386	GTO 01	442	GTO 06	498	XEQ "P"	554	CF 21
331	CHS	387	STOP	443	13	499	PSE	555	RTN
332	RCL 09	388	RTN	444	"B(00)"	500	GTO "N"	556	LBL "W"
333	/	389	LBL 01	445	XEQ 03	501	LBL 01	557	FS? 02
334	STO 14	390	PSE	446	SF 13	502	SF 21	558	"I/K"
335	FIX 3	391	RTN	447	14	503	ADV	559	.END.
336	FS? 55	392	LBL 02	448	"R(N)"	504	"Z"		

EXAMPLE 3.28

(See also p. 151 in manual)

Data from Appendix I,
Tab. 10.4

* FB 28 *

CSIRKE+CADDY

RESULTS :

Rt2. : 0.495
a : -1.085.334
b<1> : 225.316
b<2> : -10.211

r<y1.2> : 0.703
r<y2.1> : -0.701

PARAMETERS

M : 7.104
Z <OPT> : 11.033
F <OPT> : 3.928
MSY : 157.503
B<00> : 00.220
r<A> : 7.857

Y-ESTIM.:

Z : 7.500
Y : 30.149

Z : 9.000
Y : 115.393

Z : 10.000
Y : 146.694

Z : 12.000
Y : 140.027

Z : 14.000
Y : 67.670

Z : 15.000
Y : -3.142

3.29: PROGRAM DESCRIPTION FB 29

Logistic Growth Curve

The logistic growth curve has the form

$$B_t = \frac{B_{\infty}}{1 + e^{-r_m(t-t_i)}} \quad \dots 1)$$

where B_{∞} is the carrying capacity, r_m is the intrinsic rate of increase, t_i is a constant which adjusts the time scale to an origin such that $t-t_i = 0$ when $B_t = B_{\infty}/2$, and B_t is the biomass at time t (B_{∞} and B_t may be replaced by N_{∞} and N_t , respectively when equation (1) pertains to numbers).

When an estimate of B_{∞} can be obtained independently (such as by averaging $B_{\max}$ values over a certain period of time), r_m and t_i can be estimated by rewriting expression (1) in the form

$$\ln\left(\frac{B_{\infty}}{B_t} - 1\right) = r_m t_i - r_m t \quad \dots 2)$$

which has the form of a linear regression whose slope and intercept allow for the estimation of r_m and t_i , respectively.

Blueweiss et al. (1978) demonstrated that, over an extremely wide range of weights, r_m in various organisms can be estimated from the empirical equation

$$r_m = 9.13 \bar{W}^{-0.26}$$

where $\bar{W}$ is the mean body weight of the adults of the species in question, in g (see manual, Fig. 11.2).

Operating limits and warnings

All values of B_t must be less than the values of B_{∞} and greater than zero (0). When using the logistic program to fit trawl mesh selection data, care must be taken to use fractions retained that are always less than 1, but greater than 0. Also, these fractions must be plotted against the class midpoints (i.e., not against the lower class limit).

FB 29: LOGISTIC GROWTH CURVE

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM			* FB 29 *
1.	DISPLAY OF MENU			MENU:
1.1	LOGISTIC GROWTH CURVE			LOGIST. C: A
1.2	EMPIRICAL EQUATION			EMP. EQU.: B
1.3	{			MENU: C
1.4	{ SEE GENERAL			INIT.: c
1.5	{ INSTRUCTIONS			REV. INP.: D
1.6	{			REV. RES.: E
2.	<u>LOGISTIC GROWTH CURVE</u>		A	LOGIST. CURVE
2.1	OPTION:			DATA INPUT:
	INDICATE WHETHER DATA			SELECT:
	REPRESENT POPULATION SIZE			POPUL. DATA: 1
	("1") OR PERTAIN TO			SELECT. EXP.: 2
	SELECTION EXPERIMENT ("2")			
2.1.1	DATA REPRESENT POPULATION			
	SIZE	1	R/S	POP. DATA IN:
	OPTION:			WT.: 1, NO: 2
	INDICATE WHETHER POPULATION			
	SIZE IS EXPRESSED IN TERMS			
	OF WEIGHT ("1") OR REFERS			
	TO NUMBERS ("2")			
2.1.1.1	DATA EXPRESSED IN TERMS OF			
	WEIGHT	1	R/S	ENTER:
				B<00> ?
	ENTER B	B	R/S	NO. OF ROWS ?
2.1.1.2	DATA REFER TO NUMBERS	2 [∞]	R/S	ENTER:
				N<00> ?
	ENTER N	N	R/S	NO. OF ROWS ?
2.1.2	DATA PERTAIN TO SELECTION			
	EXPERIMENT	2	R/S	NO. OF ROWS ?
2.2	ENTER NO. OF ROWS	k	R/S	1. ROW:
2.3	DEPENDING ON THE OPTIONS			
	SELECTED YOU ARE REQUIRED			
	TO ENTER FOR ROW 1,2 ... k			

FB 29: LOGISTIC GROWTH CURVE

USER INSTRUCTIONS (cont.)

STEP	INSTRUCTIONS	VARIABL.	FUNCT.	PROMPTS/RESULTS
2.3.1	<u>CASE I</u>			
2.3.1.1	BIOMASS AT TIME t (IN UNITS OF WEIGHT)	B_t	R/S	B<T> ? T?
2.3.1.2	TIME t	t	R/S	(n) ROW:
2.3.2	<u>CASE II</u>			
2.3.2.1	POPULATION AT TIME t (IN NUMBERS)	N_t	R/S	N<T> ? T?
2.3.2.2	TIME t	t	R/S	(n) ROW:
2.3.3	<u>CASE III</u>			
2.3.3.1	PROBABILITY OF CAPTURE AT LENGTH L	P_L	R/S	P<L> ? LENGTH
2.3.3.2	CLASS MIDPOINT OF L	L	R/S	
2.4	DISPLAY OF RESULTS: DEPENDING ON THE OPTIONS SELECTED YOU OBTAIN:			
2.4.1	<u>CASE I & II (BIOMASS)</u>			
2.4.1.1	COEFFICIENT OF DETERMINATION [r^2]			R^2 : (x)
2.4.1.2	INTRINSIC RATE OF INCREASE [r]			$R<m>$: (x)
2.4.1.3	TIME AT INFLEXION POINT [t_i]			$T<i>$: (x)
2.4.2	<u>CASE III¹ (SELECTION EXPERIMENT):</u>			
2.4.2.1	COEFFICIENT OF DETERMINATION [r^2]			R^2 : (x)
2.4.2.2	INTRINSIC RATE OF INCREASE [r]			$R<m>$: (x)
2.4.2.3	MEAN LENGTH AT FIRST CAPTURE [L_c]			$L<c>$: (x)
2.5	OPTION :			
2.5.1	REVIEW RESULTS, PRESS		E	<RESULTS>
2.5.2	COMPUTE ESTIMATES OF B_t , N OR P_L , PRESS		R/S	
2.6	CONTINUE DEPENDING ON THE OPTIONS SELECTED			X-ESTIM.: ENTER:

FB 29: LOGISTIC GROWTH CURVE

USER INSTRUCTIONS (cont.)

STEP	INSTRUCTIONS	VARIABL.	FUNCT.	PROMPTS/RESULTS
2.6.1	CASE I ENTER TIME t RESULT: BIOMASS AT TIME t (WEIGHT)	t	R/S	T ? B< t >: (x) NEXT T?
2.6.2	CASE II ENTER TIME t RESULT: BIOMASS AT TIME t (IN NUMBERS)	t	R/S	T ? N< t >: (x) NEXT T?
2.6.3	CASE III ENTER LENGTH (CLASS MIDPOINTS) RESULT: PROBABILITY OF CAPTURE AT LENGTH L	L	R/S	LENGTH ? P< L >: (x) NEXT LENGTH
3.	<u>$\bar{r}$ FROM EMPIRICAL EQUATION</u>		B	* BLUEWEISS *
3.1	ENTER MEAN BODY WEIGHT OF ADULTS (IN g)	$\bar{w}$	R/S	MEAN WEIGHT ? R<M>: (x)
3.2	RESULT: INTRINSIC RATE OF INCREASE [r_m]			

REGISTERS, STATUS, FLAGS

PROGR. NAME: FB 29 (Logistic Growth Curve)

STATUS : REG. (PROGR.): 148
 SIZE (MIN.) : 016 SIZE (MAX.): -

FLAGS : 1, 2, 5 - 8, 10

ASSIGNMENTS:

A: GENERAL COMMANDS

B: SPECIAL COMMANDS

INITIALIZE : (f)c
REVIEW RESULTS : E
RECALL MENU : C
REVIEW DATA : D

LOGISTIC GROWTH CURVE : A
EMPIRICAL EQUATION : B

REGISTERS :

SUB- PROGR.:	A	B
00 :	[u]	
01 :	[u]	result
02 :	[u]	is
03 :	r^2	stored
04 :	a	in
05 :	b	X-register
06 :	r<m>	
07 :	t<l>/L<c>	
08 :	[u]	
09 :	(B/N)<t>/P<L>	
10 :	[u]	
11 :	[u]	
12 :	[u]	
13 :	[u]	
14 :	[u]	
15 :	[u]	

Program Listing

(FB 29)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01	LBL "FB 29"	57	LBL E	113	STO 05	169	LBL 07	225	FS? 55
02	LBL c	58	FS? 08	114	X<>Y	170	FIX 0	226	GTO 01
03	CF 21	59	GTO "0"	115	X<> 02	171	CLA	227	BEEP
04	BEEP	60	GTO "Z"	116	STO 04	172	ARCL 00	228	LBL "Z"
05	" * FB 29 *"	61	LBL A	117	FS? 06	173	"H. ROW :"	229	"R+2"
06	XEQ "Q"	62	"LOGISTIC C."	118	GTO 02	174	AVIEW	230	RCL 03
07	SF 27	63	XEQ "Q"	119	ISG 00	175	RTN	231	XEQ "P"
08	10	64	"DATA INPUT :"	120	GTO 01	176	LBL 14	232	RCL 06
09	LBL "M"	65	AVIEW	121	SF 09	177	AVIEW	233	"R(M)"
10	CF IND X	66	PSE	122	GTO 02	178	TONE 7	234	XEQ "P"
11	DSE X	67	"SELECT :"	123	LBL 01	179	PSE	235	RCL 07
12	GTO "M"	68	AVIEW	124	XEQ 07	180	"YES: 1, NO: 0"	236	"T(I)"
13	CF 00	69	PSE	125	LBL 02	181	PROMPT	237	FS? 02
14	SREG 10	70	"POPUL. DATA: 1"	126	RCL 01	182	RTN	238	"L(c)"
15	CLRG	71	AVIEW	127	RCL 04	183	LBL 04	239	XEQ "P"
16	LBL C	72	PSE	128	/	184	"PLEASE WAIT"	240	FC? 07
17	"MENU :"	73	PSE	129	1	185	AVIEW	241	STOP
18	AVIEW	74	1	130	-	186	RCL 14	242	GTO 02
19	PSE	75	STO 00	131	LN	187	RCL 10	243	LBL 01
20	PSE	76	"SELECT. EXP: 2"	132	RCL 05	188	RCL 12	244	XEQ "S"
21	"LOGIST. C.: A"	77	PROMPT	133	Σ+	189	*	245	SF 21
22	AVIEW	78	SF IND X	134	FS? 06	190	RCL 15	246	ADV
23	PSE	79	1	135	GTO 04	191	/	247	SF 13
24	PSE	80	FS? 02	136	FC? 09	192	-	248	RCL 03
25	"EMP. EQU.: B"	81	GTO 01	137	GTO "R"	193	STO 05	249	"R+2 "
26	AVIEW	82	"POP. DATA IN :"	138	SF 06	194	X+2	250	XEQ "X"
27	PSE	83	AVIEW	139	LBL D	195	RCL 13	251	RCL 06
28	PSE	84	PSE	140	"LAST INPUT :"	196	RCL 12	252	"R(M)"
29	"MENU : C"	85	"WT.: 1, NO.: 2"	141	AVIEW	197	X+2	253	XEQ "X"
30	AVIEW	86	PROMPT	142	PSE	198	RCL 15	254	RCL 07
31	PSE	87	2	143	SF 05	199	/	255	"T(I)"
32	"INIT.: c"	88	X=Y?	144	FIX 2	200	-	256	FS? 02
33	AVIEW	89	SF 10	145	XEQ "W"	201	/	257	"L(c)"
34	PSE	90	"ENTER :"	146	RCL 02	202	RCL 11	258	FS? 02
35	"REV. INPUT : D"	91	AVIEW	147	XEQ "P"	203	RCL 10	259	CF 13
36	AVIEW	92	PSE	148	"T"	204	X+2	260	XEQ "X"
37	PSE	93	"B"	149	FS? 02	205	RCL 15	261	CF 13
38	"REV. RES.: E"	94	FS? 10	150	"L"	206	/	262	CF 21
39	PROMPT	95	"H"	151	RCL 03	207	-	263	LBL 02
40	GTO C	96	"H<00> ?"	152	XEQ "P"	208	ST/ 05	264	SF 05
41	LBL B	97	PROMPT	153	CF 05	209	/	265	TONE 7
42	"*BLUEWEISS*"	98	LBL 01	154	"CORRECTION ?"	210	STO 03	266	SF 07
43	AVIEW	99	STO 01	155	XEQ 14	211	RCL 12	267	SF 05
44	PSE	100	"NO. OF ROWS ?"	156	X=0?	212	RCL 05	268	XEQ "W"
45	LBL "K"	101	PROMPT	157	GTO 01	213	RCL 10	269	"H-ESTIM.:"
46	FIX 3	102	3	158	LBL "Y"	214	*	270	XEQ "T"
47	"MEAN WEIGHT?"	103	10+X	159	XEQ 07	215	-	271	PSE
48	PROMPT	104	/	160	XEQ "W"	216	RCL 15	272	"ENTER :"
49	- .26	105	1	161	STO 03	217	/	273	AVIEW
50	Y+X	106	+	162	X<>Y	218	STO 04	274	PSE
51	9.13	107	STO 00	163	STO 02	219	RCL 05	275	PSE
52	*	108	GTO "Y"	164	ISG 00	220	ABS	276	CLA
53	"R(M) :"	109	LBL "R"	165	LBL 01	221	STO 06	277	GTO 01
54	ARCL X	110	FC? 06	166	FC? 06	222	/	278	LBL "H"
55	PROMPT	111	XEQ "W"	167	XEQ 07	223	STO 07	279	"NEXT "
56	GTO "K"	112	X<> 03	168	GTO "R"	224	FIX 3	280	LBL 01

Program Listing

(FB 29 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
281	FC? 02	337	RTN						
282	"I"	338	LBL "Q"						
283	FS? 02	339	AVIEW						
284	"LENGTH"	340	PSE						
285	FC? 02	341	FC? 55						
286	"I"	342	RTN						
287	"I?"	343	SF 21						
288	PROMPT	344	ADV						
289	SF 08	345	ADV						
290	CF 13	346	SF 12						
291	STO 08	347	GTO 01						
292	RCL 07	348	LBL "S"						
293	-	349	"RESULTS :"						
294	RCL 05	350	BEEP						
295	*	351	LBL "T"						
296	EIX	352	AVIEW						
297	1	353	FC? 55						
298	+	354	RTN						
299	1/X	355	SF 21						
300	RCL 01	356	ADV						
301	*	357	LBL 01						
302	STO 09	358	ACA						
303	FIX 3	359	PRBUF						
304	FS? 55	360	CF 12						
305	GTO 01	361	CF 21						
306	LBL "Q"	362	RTN						
307	RCL 09	363	LBL "W"						
308	XEQ "W"	364	FS? 01						
309	XEQ "P"	365	GTO 01						
310	GTO "N"	366	"P(L)"						
311	LBL 01	367	GTO 03						
312	SF 21	368	LBL 01						
313	ADV	369	"B"						
314	XEQ "U"	370	FS? 10						
315	ASTO X	371	"N"						
316	"FOR "	372	LBL 02						
317	ARCL X	373	"I(T)"						
318	RCL 08	374	LBL 03						
319	XEQ "X"	375	FS? 05						
320	XEQ "W"	376	RTN						
321	RCL 09	377	"I ?"						
322	XEQ "X"	378	PROMPT						
323	CF 21	379	LBL "U"						
324	GTO "N"	380	"T"						
325	LBL "P"	381	FS? 02						
326	"I : "	382	"LENGTH"						
327	ARCL X	383	FS? 05						
328	AVIEW	384	RTN						
329	PSE	385	"I ?"						
330	PSE	386	PROMPT						
331	RTN	387	,END.						
332	LBL "X"								
333	"I "								
334	ACA								
335	ACX								
336	PRBUF								

EXAMPLE 3.29

(See also p. 20 and 158 in manual)

Data from Appendix I,
Tab. 11.1

Data from Appendix I,
Tab. 3.1

* FB 29 *

LOGISTIC C.

RESULTS :

n₁₂ : 0.854
n<μ> : 2.244
t<1> : 3.437

B<T>-ESTIM.:

FOR T : 1.000
B<T> : 0.336

FOR T : 2.000
B<T> : 3.059

FOR T : 2.500
B<T> : 8.703

FOR T : 3.000
B<T> : 21.810

FOR T : 3.500
B<T> : 42.807

FOR T : 4.000
B<T> : 62.356

FOR T : 4.500
B<T> : 73.250

FOR T : 5.000
B<T> : 77.669

* FB 29 *

LOGISTIC C.

RESULTS :

n₁₂ : 0.938
n<μ> : 0.591
L<c> : 14.002

P<L>-ESTIM.:

FOR LENGTH : 8.000
P<L> : 0.028

FOR LENGTH : 10.000
P<L> : 0.066

FOR LENGTH : 12.000
P<L> : 0.234

FOR LENGTH : 14.000
P<L> : 0.500

FOR LENGTH : 16.000
P<L> : 0.765

FOR LENGTH : 18.000
P<L> : 0.914

FOR LENGTH : 20.000
P<L> : 0.972

FOR LENGTH : 22.000
P<L> : 0.991

FOR LENGTH : 24.000
P<L> : 0.997

3.30: PROGRAM DESCRIPTION FB 30

PART I: Asymptotic Yield Model

In multispecies stocks, due to changes in species composition, total (multispecies) yield tends to level off - rather than decline - when effort becomes very high. This effect, which precludes definition of a true "MSY", can be accounted for by using an "asymptotic yield" model to fit catch and effort data, i.e.

$$Y = Y_{\infty} (1 - e^{-\alpha f}) \quad \dots 1)$$

where Y_{∞} is the (hypothetical) yield that would be generated at an infinitely high level of effort, and α is an empirical constant. In this model, a value of $f_{0.1}$ (analogous to $F_{0.1}$) replaces f_{opt} , and $Y_{0.1}$, the yield corresponding to $f_{0.1}$, replaces MSY as defined by standard surplus production models. These new concepts are defined by

$$Y_{0.1} = Y_{\infty} \cdot 0.9 \quad \dots 2)$$

and

$$f_{0.1} = \ln(10)/\alpha \quad \dots 3)$$

For more details on the asymptotic yield model, see p. 171-173 in the manual. Note however, that the method used here to fit equation (1) to data is a proper least square minimization routine, rather than fiddling as in Example 12.2, p. 176 of the manual. This explains the slight differences between the estimates of Y_{∞} and α obtained here and those in the manual.

PART II: Yields from Two Interacting Species

Pope (1979) showed that, if single-species yield curves can be described by parabolas, the total yield (Y_T) of a system of two interacting species P and Q should, as long as the ratio $F_P:F_Q$ remains constant, also correspond to a parabola, i.e.

$$Y_T = \underbrace{aF_P - bF_P^2 + C_1 F_P F_Q^2}_{Y_P} + \underbrace{dF_Q - eF_Q^2 + C_2 F_P F_Q}_{Y_Q} \quad \dots 5)$$

where a & b, and d & e are constants of the yield curves of the two different species (e.g. predator and prey) and where C_1 and C_2 express the intensity of the interactions occurring between these species (C_1 and C_2 have opposite signs in cases of predator-prey interactions). Pope (1979) also generalized equation (4) to an n-species system and showed that the overall yield curve of such system is parabolic, as long as the F-ratios remain constant and no species drops out of the system.

Program FB 30 estimates values of Y_P , Y_Q , Y_T for any combination of a, b, C_1 , C_2 , d, e, F_Q and F_P values as well as the MSY and optimal values of F_P and F_Q of a 2 species system.

Operating Limits and Warnings

PART I. Iteration time can be rather long; don't be impatient.

PART II. There might be combinations of constants and of F_P' and F_Q' for which the MSY cannot be located by the algorithm provided here. Iteration time also can be rather long; don't be impatient.

When computing Y_P , Y_Q and Y_T , the combination of the interaction terms are omitted if one of the species drop out of the system; "dropping out" occurs when a partial yield is smaller than zero.

FB 30: MULTISPECIES YIELDS

USER INSTRUCTIONS

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
0.	LOAD PROGRAM			* FB 30 *
1.	DISPLAY OF MENU			MENU:
1.1	ASYMPTOTIC YIELD MODEL			ASYMPT. Y.: A
1.2	INTERACTING SPECIES MODEL			2-SP. MOD.: B
1.3	{			MENU : C
1.4	{ SEE GENERAL			INIT. : c
1.5	{ INSTRUCTIONS			REV. DATA : D
1.6	{			REV. RES. : E
2.	SELECT MODEL ^{a)} :			
2.1	ASYMPTOTIC YIELD		A	ASYMPT. Y.
2.2	INTERACTING SPECIES		B	2-SP. MODEL
3.	<u>ASYMPTOTIC YIELD MODEL</u>		A	ASYMPT. Y.
				DATA INP.:
				NO. OF ROWS ?
3.1	ENTER NO. OF ROWS	k	R/S	1. ROW:
3.2	ENTER FOR ROW NO. 1,2,...k			CATCH ?
3.2.1	CATCH	C	R/S	EFFORT ?
3.2.2	EFFORT	f	R/S	2. (3...k) ROW:
				PLEASE WAIT
4.	THE SEARCH ROUTINE REDUCES THE STEP SIZE 7 TIMES BEFORE IT STOPS. THE CURRENT STEP SIZE RANK IS DISPLAYED			1. RANK 2. RANK : 7. RANK (RESULTS)
5.	DISPLAY OF RESULTS:			RESULTS:
5.1	VALUE OF α			<a: (x)
5.2	ASYMPTOTIC YIELD		R/S	Y<00>: (x)
5.3	OPTIMUM EFFORT ($f_{0.1}$)		R/S	F*<0.1>: (x) (PROGR. STOP)

a) NOTE THAT YOU MUST GO THROUGH THE INITIALIZATION ROUTINE (f_c) EVERYTIME YOU SELECT A MODEL (I.E., BEFORE PRESSING A OR B)

FB 30: MULTISPECIES YIELDS

USER INSTRUCTIONS (cont.)

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
6.	OPTIONS :			
6.1	REVIEW RESULTS		E	(RESULTS)
6.2	COMPUTE YIELD FOR A GIVEN EFFORT		R/S	Y ESTIM.? F* ?
6.2.1	ENTER EFFORT	f	R/S	Y: (x) NEXT F* ?
6.2.2	REPEAT STEP 6.2.1 WITH VARIOUS f TO OBTAIN POINTS OF A YIELD CURVE			
7.	<u>TWO INTERACTING</u> <u>SPECIES MODEL</u>		B	2-SP. MODEL SELECT: YIELD C.: 1 MSY, F<OPT>: 2
8.	INDICATE WHETHER YOU WANT TO OBTAIN FOR A 2-SPECIES SYSTEM:			
8.1	COMBINED YIELD CURVES	1	R/S	CONSTANTS:
8.2	MSY, OPTIMUM F-VALUES	2	R/S	CONSTANTS: ENTER:
9.	ENTER CONSTANTS:			a ?
9.1	a	a	R/S	b ?
9.2	b	b	R/S	c<1> ?
9.3	C(1)	c(1)	R/S	d ?
9.4	d	d	R/S	e ?
9.5	e	e	R/S	c<2> ?
9.6	C(2)	c(2)	R/S	
10.	IF YOU HAVE OPTED FOR:			
10.1	YIELD CURVES, CONTINUE AT STEP 15.			
10.2	MSY, F<OPT>, CONTINUE AT STEP 11.			
11.	(CONT. FROM STEP 9.6) TO START SEARCH ROUTINE, ENTER INITIAL F-VALUE OF:			START. VALUE: F<P> ?

FB 30: MULTISPECIES YIELDS

USER INSTRUCTIONS (cont.)

STEP	INSTRUCTIONS	VARIABLE	FUNCT.	PROMPTS/RESULTS
11.1	PREY-SPECIES	$F'(P)$	R/S	$F<Q> ?$
11.2	PREDATOR-SPECIES	$F'(Q)$	R/S	:
				:
				1. RANK
12.	THE SEARCH ROUTINE REDUCES THE STEP SIZE 7 TIMES BEFORE SEARCH STOPS. THE CURRENT STEP SIZE RANK IS DISPLAYED			1. RANK
				2. RANK
				:
				7. RANK
				(RESULTS)
13.	DISPLAY OF RESULTS:			RESULTS:
13.1	OPTIMUM F-VALUE (PREDATOR)			OPT. $F<Q>$: (x)
13.2	OPTIMUM F-VALUE (PREY)		R/S	OPT. $F<P>$: (x)
13.3	MSY (WHOLE SYSTEM)		R/S	MSY : (x)
14.	OPTION:			
14.1	TO REVIEW RESULTS, PRESS		E	(RESULTS)
14.2	TO COMPUTE VALUES OF COMBINED YIELD CURVES, PRESS		R/S	YIELD CURVES
15.	<u>COMPUTATION OF YIELD CURVES</u> <u>FOR A TWO SPECIES SYSTEM</u>			YIELD CURVES
15.1	ENTER:			ENTER:
15.1.1	F-VALUE (PREDATORS)	$F(Q)$	R/S	$F<Q> ?$
15.1.2	F-VALUE (PREY)	$F(P)$	R/S	$F<P> ?$
15.2	DISPLAY OF RESULTS:			:
15.2.1	YIELD (PREDATOR)			:
15.2.2	YIELD (PREY)		R/S	$Y<Q>$: (x)
15.2.3	YIELD (WHOLE SYSTEM)		R/S	$Y<P>$: (x)
				$Y<T>$: (x)
16.	OPTION:			
16.1	TO REVIEW RESULTS, PRESS		E	(RESULTS)
16.2	TO COMPUTE ANOTHER SET OF YIELD-VALUES, PRESS		R/S	NEXT $F<Q> ?$

REGISTERS, STATUS, FLAGS

PROGR. NAME: FB 30 (Multispecies Yields)

STATUS : REG. (PROGR.): 229
 SIZE (MIN.) : 027/(k*2)+21 SIZE (MAX.): -

FLAGS : 1, 2, 5 - 10

ASSIGNMENTS:

A: GENERAL COMMANDS
 INITIALIZE : (f)c
 REVIEW RESULTS : E
 RECALL MENU : C
 REVIEW DATA : D

B: SPECIAL COMMANDS
 ASYMPTOTIC YIELD MODEL : A
 INTERACTING SPEC. MODEL.: B

REGISTERS :

SUB-
 PROGR.: A B
 00 : [u] [u]
 01 : <alpha> OPT F<Q>
 02 : Y< ∞ > OPT F<P>
 03 : f<0.1> MSY
 04 : [u] [u]
 05 : [u] [u]
 06 : [u] [u]
 07 : [u] Y<Q>
 08 : [u] Y<P>
 09 : [u] Y<T>
 10 : [u] [u]
 11 : [u] [u]
 12 : [u] [u]
 13 : [u] [u]
 14 : [u] [u]
 15 : [u] [u]
 16 : [u] [u]
 17 : [sum of [u]
 squares]
 18 : - -
 19 : [u] -
 20 : [u] -
 21 : C(1) a
 22 : f(1) b
 23 : . c(1)
 24 : . d
 25 : . e
 26 : . c(2)
 C(k)
 f(k)

 NOTE: "k" REPRESENTS NUMBER OF CASES (= NO. OF ROWS)

Program Listing

(FB 30)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
01	LBL "FB 30"	57	2	113	"NO. ?"	169	PSE	225	LBL "L"
02	LBL c	58	*	114	PROMPT	170	RTN	226	0
03	CF 21	59	1	115	2	171	LBL 13	227	STO 05
04	BEEP	60	-	116	*	172	"CORRECTION ?"	228	LBL "M"
05	* * FB 30 * "	61	+	117	19	173	LBL 14	229	1
06	XEQ "Y"	62	3	118	+	174	AVIEW	230	ST+ 05
07	SF 27	63	10+X	119	FIX 2	175	TONE 7	231	XEQ "P"
08	CLRG	64	ST/ 01	120	XEQ 11	176	PSE	232	ENTER↑
09	FIX 0	65	/	121	XEQ 10	177	"YES: 1, NO: 0"	233	X<> 06
10	10	66	+	122	1	178	PROMPT	234	X=0?
11	LBL "0"	67	STO 20	123	+	179	RTN	235	GTO 01
12	CF IND X	68	1	124	XEQ 12	180	LBL 05	236	X>Y?
13	DSE X	69	ST+ 01	125	XEQ 10	181	"F ROW "	237	GTO 02
14	GTO "0"	70	SF 06	126	XEQ 13	182	FC? 06	238	LBL 01
15	CF 00	71	"1."	127	X=0?	183	RTN	239	RCL IND 04
16	LBL C	72	XEQ 05	128	GTO 06	184	"F.:"	240	STO IND 10
17	"MENU :"	73	AVIEW	129	X<>Y	185	RTN	241	RCL IND 03
18	AVIEW	74	PSE	130	1	186	LBL 02	242	+
19	PSE	75	LBL "R"	131	-	187	CF 21	243	STO IND 04
20	PSE	76	XEQ 11	132	"CORR. INF. ?"	188	"PLEASE WAIT"	244	GTO "M"
21	"ASYMPT. Y.: A"	77	PROMPT	133	AVIEW	189	AVIEW	245	LBL 02
22	AVIEW	78	XEQ 12	134	PSE	190	RCL 19	246	RCL 05
23	PSE	79	PROMPT	135	SF 06	191	STO 02	247	3
24	PSE	80	ISG 01	136	XEQ 11	192	STO 12	248	X<=Y?
25	"2-SP. MOD.: B"	81	GTO 01	137	PROMPT	193	STO 14	249	GTO 01
26	AVIEW	82	SF 09	138	STO IND Y	194	-.1	250	-1
27	PSE	83	GTO 02	139	RDN	195	STO 01	251	ST+ IND 03
28	PSE	84	LBL 01	140	1	196	STO 11	252	GTO "L"
29	"MENU : C"	85	CLA	141	+	197	STO 13	253	LBL 01
30	AVIEW	86	ARCL 01	142	STO 32	198	XEQ "K"	254	RCL IND 10
31	PSE	87	"F."	143	XEQ 12	199	10	255	STO IND 04
32	PSE	88	XEQ 05	144	PROMPT	200	LN	256	1
33	"INIT.: c"	89	AVIEW	145	STO IND Y	201	RCL 01	257	ST+ 10
34	AVIEW	90	LBL 02	146	CF 06	202	/	258	ST+ 03
35	PSE	91	X<>Y	147	LBL 06	203	CHS	259	0
36	PSE	92	RCL 19	148	"MORE "	204	STO 03	260	STO 06
37	"REV. DATA : D"	93	X<>Y	149	LBL 07	205	XEQ "W"	261	ISG 04
38	AVIEW	94	X>Y?	150	"PREVIEW?"	206	GTO c	262	GTO "L"
39	PSE	95	STO 19	151	XEQ 14	207	LBL "K"	263	GTO "K"
40	PSE	96	STO IND 20	152	X=0?	208	7	264	LBL 06
41	"REV. RES.: E"	97	ISG 20	153	GTO "S"	209	RCL 00	265	CLA
42	PROMPT	98	RCL 2	154	GTO 02	210	X=Y?	266	FIX 0
43	GTO C	99	STO IND 20	155	LBL 11	211	RTN	267	ARCL X
44	LBL A	100	FS?C 09	156	"CATCH"	212	1	268	"F. RANK"
45	"ASYMPT. Y."	101	GTO 01	157	GTO 01	213	+	269	AVIEW
46	XEQ "Y"	102	ISG 20	158	LBL 12	214	STO 00	270	RTN
47	SF 10	103	GTO "R"	159	"EFFORT"	215	XEQ 08	271	LBL "P"
48	"DATA INP.:"	104	LBL 01	160	LBL 01	216	1.002	272	FC? 10
49	AVIEW	105	CF 06	161	FC? 06	217	STO 04	273	GTO "0"
50	PSE	106	CLA	162	RTN	218	2	274	RCL 20
51	21	107	GTO 07	163	"F ?"	219	ST/ 13	275	FRC
52	ENTER↑	108	LBL D	164	RTN	220	ST/ 14	276	21
53	ENTER↑	109	LBL "S"	165	LBL 10	221	13	277	+
54	"NO. OF ROWS ?"	110	CF 06	166	"F : "	222	STO 03	278	STO 20
55	PROMPT	111	CLA	167	ARCL IND X	223	11	279	0
56	STO 01	112	XEQ 05	168	AVIEW	224	STO 10	280	STO 17

Program Listing

(FB 30 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
281	LBL "U"	337	RTN	393	X=0?	449	SF 06	505	LBL 01
282	RCL IND 20	338	RCL 07	394	RCL 01	450	CF 07	506	FC? 21
283	ISG 20	339	+	395	STO 13	451	CF 08	507	GTO 01
284	1	340	RTN	396	STO 14	452	XEQ "0"	508	1
285	RCL IND 20	341	LBL B	397	XEQ "K"	453	0	509	"0"
286	RCL 01	342	CF 01	398	XEQ "0"	454	FS? 08	510	XEQ 02
287	*	343	CF 02	399	STO 03	455	GTO 01	511	"P"
288	E+X	344	"2-SP. MODEL"	400	XEQ "W"	456	FS? 07	512	XEQ 02
289	-	345	XEQ "Y"	401	GTO e	457	GTO 02	513	LBL 01
290	RCL 02	346	"SELECT :"	402	LBL 06	458	GTO 00	514	FIX 0
291	*	347	AVIEW	403	FS? 55	459	LBL 01	515	7
292	-	348	PSE	404	"F"	460	FS? 07	516	"0"
293	X+2	349	"YIELD C.: 1"	405	LBL 03	461	GTO 01	517	XEQ 03
294	ST+ 17	350	AVIEW	406	FS? 55	462	STO 07	518	"P"
295	ISG 20	351	PSE	407	XEQ 04	463	RCL 08	519	XEQ 03
296	GTO "U"	352	"MSY, F(OPT): 2"	408	"F ?"	464	RCL 16	520	"T"
297	RCL 17	353	PROMPT	409	PROMPT	465	-	521	GTO 03
298	1/X	354	SF IND X	410	STO IND Y	466	X<0?	522	LBL 02
299	RTN	355	"CONSTANTS :"	411	FS? 55	467	0	523	ENTER+
300	LBL "0"	356	XEQ "T"	412	XEQ 05	468	STO 08	524	ASTO X
301	RCL 21	357	"ENTER :"	413	X<Y	469	GTO 00	525	"F"
302	RCL 02	358	AVIEW	414	1	470	LBL 02	526	GTO 01
303	*	359	PSE	415	+	471	STO 08	527	LBL 03
304	RCL 22	360	21	416	RTN	472	RCL 07	528	ENTER+
305	RCL 02	361	"a"	417	LBL 04	473	RCL 15	529	ASTO X
306	X+2	362	XEQ 06	418	SF 21	474	-	530	"Y"
307	*	363	"b"	419	ACA	475	X<0?	531	LBL 01
308	-	364	XEQ 06	420	CF 21	476	0	532	"F<"
309	RCL 23	365	"c<1>"	421	RTN	477	STO 07	533	ARCL X
310	RCL 01	366	XEQ 03	422	LBL 05	478	GTO 00	534	"F>"
311	RCL 02	367	"d"	423	SF 21	479	LBL 01	535	X<Y
312	*	368	XEQ 06	424	CLA	480	0	536	FS? 21
313	STO 16	369	"e"	425	"F :"	481	STO 07	537	GTO 09
314	*	370	XEQ 06	426	ACA	482	STO 08	538	GTO 08
315	STO 15	371	"c<2>"	427	ACX	483	LBL 00	539	LBL 05
316	+	372	XEQ 03	428	PRBUF	484	RCL 07	540	FIX 3
317	X<0?	373	FS? 01	429	CF 21	485	ENTER+	541	FS? 55
318	SF 08	374	GTO "X"	430	RTN	486	X<> 08	542	GTO 01
319	STO 07	375	SF 21	431	LBL "X"	487	STO 07	543	1
320	RCL 24	376	ADV	432	TONE 7	488	+	544	"<a"
321	RCL 01	377	CF 21	433	"YIELD CURVES"	489	STO 09	545	XEQ 08
322	*	378	"START. VALUE :"	434	XEQ "T"	490	LBL e	546	FIX 0
323	RCL 25	379	AVIEW	435	"ENTER :"	491	CF 05	547	"Y<00>"
324	RCL 01	380	PSE	436	AVIEW	492	SF 21	548	XEQ 08
325	X+2	381	FIX 2	437	PSE	493	ADV	549	FIX 2
326	*	382	1	438	CLA	494	LBL E	550	"F*<0.1>"
327	-	383	"F<P>"	439	GTO 01	495	CF 21	551	XEQ 08
328	RCL 26	384	XEQ 03	440	LBL "V"	496	FS? 10	552	GTO 00
329	RCL 16	385	"F<Q>"	441	"NEXT"	497	GTO 05	553	LBL 01
330	*	386	XEQ 03	442	LBL 01	498	FS? 02	554	SF 21
331	STO 16	387	RCL 01	443	"F<Q> ?"	499	GTO 06	555	CLA
332	+	388	ENTER+	444	PROMPT	500	FIX 2	556	4
333	X<0?	389	X<> 02	445	STO 01	501	FS? 55	557	ACCHR
334	SF 07	390	STO 01	446	"F<P> ?"	502	SF 21	558	"F"
335	STO 08	391	-	447	PROMPT	503	XEQ 01	559	1
336	FS? 06	392	ABS	448	STO 02	504	GTO 08	560	XEQ 09

Program Listing

(FB 30 cont.)

STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY	STEP	KEY ENTRY
561	FIX 0	617	1	673	"Y"				
562	"Y<00>"	618	+	674	XEQ 09				
563	XEQ 09	619	RTN	675	CF 21				
564	SF 13	620	*LBL 00	676	GTO "N"				
565	FIX 2	621	CF 21	677	*LBL "W"				
566	"F<0.1>"	622	SF 05	678	"RESULTS :"				
567	XEQ 09	623	FS? 10	679	BEEP				
568	CF 13	624	GTO 01	680	*LBL "T"				
569	GTO 00	625	FS? 01	681	AVIEW				
570	*LBL 06	626	GTO "V"	682	PSE				
571	FIX 2	627	CF 02	683	FC? 55				
572	FS? 55	628	SF 01	684	RTN				
573	SF 21	629	GTO "X"	685	SF 21				
574	XEQ 02	630	*LBL 01	686	ADV				
575	GTO 00	631	CF 05	687	GTO 01				
576	*LBL 02	632	TONE 7	688	*LBL "Y"				
577	1	633	"Y ESTIM. :"	689	AVIEW				
578	"Q"	634	XEQ "T"	690	PSE				
579	XEQ 01	635	PSE	691	FC? 55				
580	"P"	636	"ENTER :"	692	RTN				
581	XEQ 01	637	AVIEW	693	SF 21				
582	FIX 0	638	PSE	694	ADV				
583	"MSY"	639	PSE	695	ADV				
584	FS? 21	640	CLA	696	SF 12				
585	GTO 09	641	GTO 01	697	*LBL 01				
586	GTO 08	642	*LBL "N"	698	ACA				
587	*LBL 01	643	"NEXT "	699	PRBUF				
588	XEQ 02	644	*LBL 01	700	CF 21				
589	FS? 21	645	1	701	CF 12				
590	GTO 09	646	"HF? ?"	702	.END.				
591	GTO 08	647	PROMPT						
592	*LBL 02	648	GTO 04						
593	ENTER↑	649	FIX 0						
594	ASTO X	650	RCL 01						
595	"OPT. F<"	651	*						
596	ARCL X	652	ETX						
597	"↑)"	653	-						
598	X<Y	654	RCL 02						
599	RTN	655	*						
600	*LBL 08	656	GTO 05						
601	*LBL "Z"	657	FS? 55						
602	"↑ : "	658	GTO 01						
603	ARCL IND X	659	"Y"						
604	AVIEW	660	5						
605	PSE	661	XEQ "Z"						
606	FC? 05	662	GTO "N"						
607	STOP	663	*LBL 01						
608	GTO 01	664	SF 21						
609	*LBL 09	665	ADV						
610	"↑ : "	666	SF 13						
611	ACA	667	FIX 2						
612	RCL IND X	668	"F"						
613	ACX	669	4						
614	PRBUF	670	XEQ 09						
615	X<Y	671	CF 13						
616	*LBL 01	672	FIX 0						

EXAMPLE 3.30

(See also p. 160 in manual)

Data from Appendix I,
Tab. 12.4

* FB 30 *

ASYMPT. Y.

RESULTS :

a : -0.345
Y<00> : 744.
f<0.1> : 6.68

Y ESTIM. :

f : 0.05
Y : 13.

f : 0.15
Y : 37.

* FB 30 *

2-SP. MODEL

CONSTANTS :

a : 200.
b : 100.
c<1> : -25.
d : 100.
e : 50.
c<2> : 25.

F<P> : 1.20
F<Q> : 0.00

RESULTS :

OPT. F<Q> : 1.00
OPT. F<P> : 1.00
MSY : 150.

YIELD CURVES

F<Q> : 2.00
F<P> : 0.00
Y<Q> : 0.
Y<P> : 0.
Y<T> : 0.

F<Q> : 1.50
F<P> : 0.00
Y<Q> : 38.
Y<P> : 0.
Y<T> : 38.

F<Q> : 1.50
F<P> : 1.00
Y<Q> : 75.
Y<P> : 63.
Y<T> : 138.

F<Q> : 1.00
F<P> : 1.00
Y<Q> : 75.
Y<P> : 75.
Y<T> : 150.

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APPENDIX I

Tables with Data for Testing Programs

The following Tables were extracted from the manual to help in illustrating the application and to allow testing of program FB 1 to FB 30. The original numbering of these tables was retained, where the first number refers to that of the chapter, the second that of the table itself.

Reproduced here are:

Table 2.1 (from p. 6)
" 2.2 (" " 7)
" 3.1 (" " 10)
" 3.3 (" " 14)
" 3.4 (" " 17)
" 4.2 (" " 27)
" 4.3 (" " 28)
" 4.4 (" " 30)
" 4.5 (" " 33)
" 4.6 (" " 34)
" 4.7 (" " 39)
" 5.4 (" " 60)
" 5.8 (" " 69)
" 5.10 (" " 70)

Table 6.2 (from p. 94)
" 6.3 (" " 94)
" 7.2 (" " 103)
" 7.5 (" " 106)
" 7.6 (" " 107)
" 7.7 (" " 108)
" 9.1 (" " 132)
" 9.2 (" " 133)
" 10.1 (" " 141)
" 10.2 (" " 143)
" 10.3 (" " 145)
" 10.4 (" " 147)
" 11.1 (" " 153)
" 12.4 (" " 173)

Table 2.1. Data for establishing a length-weight relationship for the threadfin bream (*Nemipterus marginatus*) from the southern tip of the South China Sea (live weight in g).

#	TL (cm)	W (g)	#	TL (cm)	W (g)
1	8.1	6.3	9	16.6	65.5
2	9.1	9.6	10	17.7	69.4
3	10.2	11.6	11	18.7	76.4
4	11.9	18.5	12	19.0	82.5
5	12.2	26.2	13	20.6	106.6
6	13.8	36.1	14	21.9	113.8
7	14.8	40.1	15	22.9	169.8
8	15.7	47.3	16	23.5	173.3

Table 2.2. Data for establishing the length-weight relationship of *Leiognathus splendens* from the Eastern Java Sea (total length in cm, live weight in g).

#	Class limits low high	Class midlength	Mean weight	n
1	6.00-6.49	6.25	5.28	1
2	6.50-6.99	6.75	4.07	1
3	7.00-7.49	7.25	6.91	11
4	7.50-7.99	7.75	8.46	26
5	8.00-8.49	8.25	10.15	26
6	8.50-8.99	8.75	11.88	23
7	9.00-9.49	9.25	13.77	16
8	9.50-9.99	9.75	17.13	2
9	10.00-10.49	10.25	19.29	7
10	10.50-10.99	10.75	22.57	9
11	11.00-11.49	11.25	25.54	7
12	11.50-11.99	11.75	28.66	3
13	12.00-12.49	12.25	34.02	7
—	12.50-12.99	12.75	—	0
14	13.00-13.49	13.25	46.73	1
—	13.50-13.99	13.75	—	0
15	14.00-14.49	14.25	55.91	1
16	14.50-14.99	14.75	65.63	1
17	15.00-15.49	15.25	61.72	1

Table 3.1. Trawl selection data for *Leiognathus equulus* obtained with 7.8-cm meshed nets in Mombasa Harbour, Kenya.^a

Lower class limit (cm)	Fishes in cover (No.)	Fishes in cod end (No.)	Total fish caught	P = fishes in cod end as fraction of total (= fraction retained)
8 = $L_{\min}$	4	0	4	0.000
9	35	2	37	0.054
10	198	22	220	0.100
11	170	56	226	0.248
12	76	42	118	0.356
13	45	34	79	0.430
14	25	19	44	0.432
15	7	21	28	0.750
16	0	12	12	1.000
17	1	3	4	0.750
18	0	5	5	1.000
19	0	5	5	1.000
20	0	3	3	1.000
21	0	1	1	1.000
22	0	1	1	1.000
23 = L_n	0	1	1	1.000
24 = $L_n + 1$	—	—	—	$\Sigma P_i = 10.120$

^aBased on selection experiments conducted during the FAO/DANIDA Training Course on the Methodology of Fisheries Sciences (Biology), held in Mombasa, Kenya, 19 May-14 June 1980.

Table 3.3. Catch by length of two gillnets to estimate their selection for *Tilapia esculenta* in Lake Victoria. Simplified from Table 1 in Garrod (1961).

Midpoint of length group (in cm)	Mesh sizes (cm)		
	8.1	9.1 ^a	
18.5	7	—	} not used, no catch with 9.1-cm meshes
19.5	90	1	
20.5	199	9	
21.5	182	53	} used, n = 5
22.5	119	290	
23.5	29	357	
24.5	17	225	} not used, see Fig. 3.3
25.5	3	82	
26.5	—	19	
27.5	—	10	} not used, no catch with 8.1-cm meshes

^aNote that, when comparing two nets, only those lengths can be used for which there are non-zero catch data on both sides.

Table 3.4. Catch by length of two gillnets for estimation of their selection for *Tilapia galilaea* in Volta Lake, Ghana.^a

Midpoint of length class (cm) ^b	Mesh sizes (cm)		Probability of capture at mesh sizes	
	7.6	10.2	7.6 cm	10.2 cm
No. of fish caught				
17.5	75	1	0.803	0.016
19.5	95	7	0.994	0.068
21.5	36	15	0.929	0.190
23.5	14	6	0.705	0.391
25.5	5	10	0.457	0.633
27.5	2	4	0.262	0.849

^aData read off Fig. 1 in Lelek and Wuddah (1969), including only those lengths for which both mesh sizes had non-zero catches.

^bData regrouped in 2-cm classes to reduce number of classes with zero catches.

Table 4.2. A set of length-at-(absolute) age data, pertaining to millet-seed butterflyfish (*Chaetodon miliaris*) from Oahu, Hawaii.^a

Specimen	Standard length (mm)	No. of daily rings
1	27	35
2	29	71
3	32	51
4	35	108
5	42	133
6	44	118
7	50	115
8	52	138
9	56	147
10	66	169
11	70	227
12	71	228
13	71	221
14	86	322
15	87	375

^aFrom Table 1 in Ralston (1976).

Table 4.3. A set of length-at-(relative) age data, pertaining to male Nile carps (*Labeo niloticus*) from a freshwater body near Alexandria (Egypt).^a

Age group (relative age, in years)	Length (cm)	N
I	19.6	184
II	37.4	73
III	45.7	11
IV	51.0	3

^aFrom Hashem (1972).

Table 4.4. Length-at-age data for the Atlantic yellowfin (*Thunnus albacares*)^a off Senegal for use with a Ford-Walford plot.

Age (years)	FL (cm)	Rearrangement for Ford-Walford plot	
		$L_t (= x)$	$L_{t+1} (= y)$
1	35		
2	55	35	55
3	75	55	75
4	90	75	90
5	105	90	105
6	115	105	115

^aFrom Postel (1955), who also gives $L_{\max} = 146.5$, corresponding to a value of $W_{\max} \approx 60$ kg.

Table 4.5. Length at tagging (L_1), length at recapture (L_2) and time at large for tagged ocean surgeon fish (*Acanthurus bahianus*) from the Virgin Islands.^a

No.	L_1 (cm)	L_2	Days out	Annual K^b	Mean temp. ^c (in °C)
1	9.7	10.2	53	0.370	27.48
2	10.5	10.9	33	0.518	28.61
3	10.9	11.8	108	0.385	27.79
4	11.1	12.0	102	0.419	29.29
5	12.4	15.5	272	0.808	28.37
6	12.8	13.6	48	1.007	28.89
7	14.0	14.3	53	0.405	27.55
8	16.1	16.4	73	0.500	27.99
9	16.3	16.5	63	0.407	27.54
10	17.0	17.2	106	0.321	28.00
11	17.7	18.0	111	0.707	28.30
				$\bar{K} = 0.532$	
				C.V. = 0.408	

^aAdapted from Table 3 of Randall (1962). Data included pertain to fishes which grew at least 2 mm while at large, which accounts for small measurement errors and cases of no-growth due to tagging wounds.

^bAs calculated from a Munro plot (see Example 4.6) with $L_{\infty} = 19.25$ cm and $D = 1$ (Fig. 4.9).

^cAs computed from the mean monthly temperatures and the dates at tagging and recapture in Randall (1962), who also gives 29.4°C as highest mean monthly temperature (T_s), 27.2°C as lowest mean monthly temperature (T_w) and 28.5°C as annual mean ($\bar{T}$).

Table 4.6. Length at tagging (L_1), length at recapture (L_2) and days at large of tagged Queen parrot fish (*Scarus vetula*) from the Virgin Islands.^a

No.	L_1 (cm)	L_2	Days out	L	cm/day
1	14.0	16.9	48	15.45	0.0604
2	20.8	27.6	189	24.2	0.0360
3	24.8	26.5	48	25.65	0.0354
$\bar{x} = 21.77$; $\bar{y} = 0.0439$					

^aAdapted from Table 17 in Randall (1962). Randall (1968) gives for this stock a value of $L_{\max} = \text{"20 inches"}$, hence $L_{(\infty)} = 20 \cdot 2.54 / 0.95 = 53.5$ cm.

Table 4.7. Seasonal growth of halfbeak (*Hemirhamphus brasiliensis*) off Western Florida, U.S.A.^a

Relative age in months	FL (cm)	Relative age in months	FL (cm)
3	16.8	12	22.2
4	18.9	13	22.5
5	19.4	14	23.2
6	20.0	15	23.6
7	19.8	16	25.0
8	21.0	18	25.5
9	20.8	21	26.4
10	21.5	24	26.4
11	21.5	—	—

^aAs read off Fig. 5 in Berkeley and Houde (1978), who also give 31 cm for $FL_{\max}$.

Table 5.4. Data for the estimation of Z/K and Z for the banded grouper (*Epinephelus sexfasciatus*) of the Visayan Sea, Philippines (from Pauly and Ingles 1981).^a

Lower class limit (cm)	Midpoint of class (cm)	N ^b
4	5	5
6	7	29
8	9	114
10	11	161
12	13	143
14	15	118
16	17	61
18	19	50
20	21	32
22	23	17
24	25	4
26	27	4

^aTo be used in conjunction with $L_{\infty} = 30.9$, $K = 0.51$ and $D = 1$.

^bAs obtained by pooling a number of samples representing a whole year.

Table 5.8. Length-frequency data for the goby (*Glossogobius giurus*) from Cardona, Laguna de Bay, Philippines.^a

Lower class limit (cm)	1958								1959			
	A	S	O	N	D	J	F	M	A	M	J	J
4	1	3	—	—	—	—	—	—	—	—	—	—
6	138	113	1	9	2	—	—	—	—	—	—	—
8	153	62	40	65	126	12	5	6	—	—	—	—
10	49	36	111	49	127	55	52	56	21	—	—	—
12	9	25	43	20	65	50	84	77	50	6	3	8
14	—	7	3	1	14	25	36	38	53	37	6	36
16	—	1	—	—	3	9	4	8	26	43	17	18
18	—	—	—	—	—	—	—	3	12	15	13	4
20	—	—	—	—	—	—	—	1	4	6	5	3
22	—	—	—	—	—	—	—	—	1	4	—	2
24	—	—	—	—	—	—	—	—	—	1	—	—
Σ	350	247	198	144	337	151	181	189	167	112	44	71
Mean length	8.58	8.93	11.07	10.15	10.83	12.52	12.80	10.99	14.69	16.89	17.50	15.99
Inputs	$\bar{L}_1 = 9.5$ (Sept)								$\bar{L}_2 = 16.8$ (June)			

^aAdapted from data in Marquez (1960).

Table 5.10. Number of tagged and recovered chub mackerels (*Rastrelliger neglectus*), grouped according to time spent at large after releasing.^a

No. of month (r') ^b	No. of recoveries
0	1,052
1	748
2	165
3	46
4	8

^aArea II, Gulf of Thailand, 1961 experiment. Total number released was $N_0 = 5,230$. From Table XXI in Hongskul (1974).

^bThe first time period at large is coded 0, the following periods 1, 2, 3, etc.

Table 6.2. Successive sample sizes of reef eels (*Kaupichthys hyoprорoides*) from an isolated Bahamian patch reef.^a

Samples	No. of fish collected	Effort ^b
A	5	1
B	4	1
C	3	1
D + E	1	2

^aBased on data in Smith (1973, Table 5, Station I).

^bThe unit of effort is "22 fluid ounces of emulsified rotenone applied from a plastic squeeze bottle".

Table 6.3. Successive sample sizes of bluehead wrasses (*Thalassoma bifasciatum*) from an isolated Bahamian patch reef.^a

Samples	No. of fish collected	Effort ^b
A	8	1
B	5	1
C	4	1

^aBased on data in Smith (1973, Table 6, Station X).

^bThe unit of effort is "22 fluid ounces of emulsified rotenone applied from a plastic squeeze bottle".

Table 7.2. Comparison of results obtained using Jones' length cohort analysis and VPA using catch-at-length data on *Merluccius merluccius* off Senegal.

Length (cm)	Catch ^a ('000)	Population ('000)			Fishing mortality (annual basis)		
		A	B	C (% diff.)	A	B	C (% diff.)
6	1,823	98,919	98,238	-0.7	0.040	0.040	0.0
12	14,463	84,393	83,801	-0.7	0.386	0.392	1.3
18	25,227	59,476	59,010	-0.8	1.066	1.111	4.2
24	8,134	27,623	27,428	-0.7	0.647	0.661	2.2
30	3,889	15,968	15,849	-0.7	0.491	0.500	1.8
36	2,959	9,861	9,782	-0.8	0.592	0.605	2.4
42	1,871	5,501	5,455	-0.8	0.647	0.666	3.1
48	653	2,819	2,797	-0.8	0.385	0.392	1.8
54	322	1,691	1,678	-0.8	0.288	0.293	1.7
60	228	1,057	1,048	-0.9	0.307	0.313	1.6
66	181	621	616	-0.8	0.401	0.412	2.7
72	96	314	312	-0.6	0.389	0.399	2.6
78	16	149	148	0.0	0.110	0.111	0.9
84 (L_{ter})	46 (C_t)	92 (N_t)	92 (N_t)	—	0.280 (F_t)	0.280 (F_t)	—

^aFrom Table 6 in Anon. (1978b) who also provided (for $D = 1$): $L_{\infty} = 130$ cm, $K = 0.1$ and $M = 0.28$.

A = Jones' length cohort analysis.

B = New method (VPA with length-at-age data).

C = $(B/A - 1) \cdot 100 = C$ (% diff.).

Table 7.5. Estimation by means of Gulland's virtual population analysis of the population (in numbers) and the fishing mortality (F) of a cohort of sardines (*Sardina pilchardus*) caught off Morocco.^a

Year of capture	Trimester	Catch	Population	F (per trimester)	Annual F
1973	3	15,624	14,382,198	0.00	
	4	139,836	11,761,034	0.01	
1974	1	66,207	9,502,830	0.01	≈ 0.18 (1974)
	2	33,191	7,720,459	0.00	
	3	514,256	6,290,998	0.09	
	4	319,612	4,686,819	0.08	
1975	1	106,583	3,548,903	0.03	≈ 0.75 (1975)
	2	383,842	2,809,370	0.16	
	3	235,246	1,954,320	0.14	
	4	434,354	1,388,058	0.42	
1976	1	37,926	746,801	0.06	≈ 0.65 (1976)
	2	39,819	577,202	0.08	
	3	118,049	436,651	0.35	
	4	34,226	251,483	0.16	
1977	1	5,225	175,063	0.03	
	2	7,859	138,612	0.06	
	3	17,538 (C _t)	106,394 (N _t)	0.20 (F _t)	

^aFrom Anon. (1978a, Table 1, p. 33) who also suggests values of $M = 0.8$ (per year, hence 0.2 per trimester) and of $F_t = 0.8$ (per year, hence 0.2 per trimester).

(See next page for Table 7.6)

Table 7.7. Estimation of population size and exploitation rate for a West African stock of hake (*Merluccius merluccius*) based on Jones' length cohort analysis.^a

Length (in cm)	Catch (in thousands)	Population (in thousands)	Exploitation rate (F/Z)	Annual Z	Annual F
6	1,823	98,919	0.13	0.32	0.04
12	14,463	84,393	0.58	0.67	0.39
18	25,227	59,476	0.79	1.35	1.07
24	8,134	27,623	0.70	0.93	0.65
30	3,889	15,968	0.64	0.77	0.49
36	2,959	9,861	0.68	0.87	0.59
42	1,871	5,501	0.70	0.93	0.65
48	653	2,819	0.58	0.67	0.39
54	322	1,691	0.51	0.57	0.29
60	228	1,057	0.52	0.59	0.31
66	181	621	0.59	0.68	0.40
72	96	314	0.58	0.67	0.39
78	16	149	0.28	0.39	0.11
84 (L _{ter})	46 (C _t)	92 (N _t)	0.50 (E _t)	(0.56)	(0.28)

^aThe catch-at-length data are from Anon. (1978b, Table 6, p. 78) from which (p. 17) the parameter values $L_\infty = 130$, $K = 0.10$, $M = 0.28$, $M/KD = 2.8$ and $D = 1$ also stem. The results (population estimates and E-values) presented here differ from those in Anon. (1978b) both because of the different E_t used, and because of various inconsistencies in the original analysis.

Table 7.6. Estimation of the population size in numbers (N) and fishing mortality (F) of a cohort of Peruvian anchovy (*Engraulis ringens*) by means of Pope's cohort analysis.

Year	Time of capture Months	Catch ^a (in millions of individuals)	N ^b (in millions)	F ^c (per 2 months)	F ^d (per 2 months)	F ^e (per 2 months)
1968	Nov-Dec	8,230	1,858,412	0.00	0.00	0.00
1969	Jan-Feb	120,060	1,514,092	0.09	0.09	0.09
	Mar-Apr	168,580	1,130,999	0.18	0.18	0.18
	May-June	21,380	773,446	0.03	0.03	0.03
	Jul-Aug	0	613,899	0.00	0.00	0.00
	Sep-Oct	21,860	502,618	0.05	0.05	0.05
	Nov-Dec	7,410	391,729	0.02	0.02	0.02
1970	Jan-Feb	7,390	314,016	0.03	0.03	0.03
	Mar-Apr	15,560	250,408	0.07	0.07	0.07
	May-June	6,420	190,937	0.04	0.04	0.04
	Jul-Aug	0	150,517	0.00	0.00	0.00
	Sep-Oct	43,310	123,233	0.49	0.47	0.50
	Nov-Dec	27,220	61,706	0.67	0.62	0.69
1971	Jan-Feb	0	25,891	0.00	0.00	0.00
	Mar-Apr	11,160	21,198	0.87	0.75	0.94
	May-June	1,290	7,257	0.22	0.17	0.25
	Jul-Aug	0	4,775	0.00	0.00	0.00
	Sep-Oct	1,020	3,909	0.34	0.25	0.41
	Nov-Dec	1,160	2,278	0.83	0.51	1.21
1972	Jan-Feb	0	815	0.00	0.00	0.00
	Mar-Apr	110 C _t	N _t = 667	F _t = 0.20	F _t = 0.10	F _t = 0.40

^aData adapted from Table 8.6 of Ricker (1975). Note that both F and M refer to a 2-month period and should be multiplied by 6 to obtain annual rates (e.g., M = 0.2 = 1.2/6).

^bRounded figures. Actual computation (based on F_t = 0.20) used 10 significant digits.

^cAssuming F_t = 0.20 and M = 0.20, which provide, with equation (7.2) the estimate of N_t = 667.

^dAssuming F_t = 0.10 and M = 0.20, population estimates omitted. Note convergence toward the F-values obtained by using F_t = 0.20.

^eAssuming F_t = 0.40 and M = 0.20, population estimates omitted. Note convergence toward the F-values obtained by using F_t = 0.20 or F_t = 0.10.

Table 9.1. Data for the derivation of a Beverton and Holt type relationship for sea bream (*Taigus tumifrons*) from the East China Sea. Figures derived from Murphy (1972, Fig. 3, based on Shindo 1960).

No.	Year	Eggs spawned No. x 10 ⁶	Recruits No. x 10 ³	P/R
1	1949	122	9.2	13.3
2	1950	84	7.2	11.7
3	1951	60	6.3	9.52
4	1952	40	9.4	4.26
5	1953	72	8.4	8.57
6	1954	42	8.3	5.06
7	1955	45	11.0	4.09
not used ^a	1956	(38)	(13.0)	(2.92)

^aUse of the 1956 value generates a negative intercept in equation (9.2), and hence a negative value of β in equation (9.1). See Users' Instruction for FB 24.

Table 9.2. Data for the derivation of Ricker type stock-recruitment relationships for the false trevally (*Lactarius lactarius*) from the Gulf of Thailand.^a

Year	P (in thousand tonnes)	R (in millions)	R (in units of P) ^b
virgin stock	2,660	—	(2,660)
1963	2,087	239	4,606.8
1966	1,277	292	5,628.4
1967	422	138	2,660.0
1968	444	202	3,893.6
1969	191	90.8	1,750.2
1970	29.8	15.5	298.77
1971	37.8	55.5	1,069.8
1972	4.0	8.9	171.55

^aFrom Pauly (1980b); the values presented here should be considered tentative due to several approximations made for the estimation of the number of recruits.

^bSee Example 9.3.

Table 10.1. Catch-and-effort data for anchoveta (*Engraulis ringens*) off Peru, prior to stock collapse (from Murphy 1972).

No.	Season	Total catch ^a (t x 10 ⁶)	Total effort ^b
1	1960-61	32.89	31.413
2	1961-62	37.78	32.999
3	1962-63	33.25	36.579
4	1963-64	28.86	40.367
5	1964-65	26.82	43.191
6	1965-66	22.26	42.716
7	1966-67	23.73	41.636
8	1967-68	25.04	44.634
9	1968-69	22.77	49.284
10	1969-70	22.64	52.048

^aThis "catch" accounts for the fish taken by the fishery, by guano birds and by fish predation.

^bThis "effort" accounts for both the fishery and the predatory animals (fish and birds) but is expressed in thousand of boat-tonnes per day.

Table 10.2. Catch-and-effort data for the red snapper fishery on Campeche Bank, Gulf of Mexico, illustrating Gulland's method to simulate equilibrium conditions. From Klima (1976, Table 8, Figs. 2 and 3).

No.	Year	Catch (t x 10 ³)	Contemporary effort (man-days at sea x 10 ³)	Average effort I (contemp. + previous year)	Average effort II (contemp. + 2 preceding years)
1	1937	4.91	227	—	—
2	1938	5.02	224	225.5	—
3	1939	4.25	220	222.0	223.7
4	1940	4.14	227	223.5	223.7
5	1941	4.79	201	214.0	216.0
6	1942	3.46	141	171.0	189.7
7	1943	3.57	125	133.0	155.7
8	1944	3.77	123	124.0	129.7
9	1945	3.98	145	134.0	131.0
10	1946	4.37	149	147.0	135.0
11	1947	4.24	164	156.5	152.7
12	1948	5.06	182	173.0	165.0
13	1949	4.79	179	180.5	175.0
14	1950	4.38	166	172.5	175.7
15	1951	3.53	156	161.0	167.0

Table 10.3. Catch-and-effort data from the north Java demersal trawl fishery (all species aggregated) (from Dwiponggo 1979).

No.	Year	Catch t x 10 ³	Effort No. of standard vessels
1	1969	50	623
2	1970	49	628
3	1971	47.5	520
4	1972	45	513
5	1973	51	661
6	1974	56	919
7	1975	66	1,158
8	1976	58	1,970
9	1977	52	1,317

Table 10.4. Catch and total mortality estimates of shorthead anchovy (*Stolephorus heterolobus*) in Ysabel Passage, near New Hanover, Papua New Guinea. Data from Dalzell (1984); Z estimates based on mean lengths.

No.	Year	Catch (t)	Total mortality (Z)
1	1972	14	7.6
2	1973	138	8.8
3	1976	191	11.0
4	1977	138	10.2
not used	1978	(404)	(11.7)
5	1979	192	9.6
6	1980	72	14.0
7	1981	66	10.5

Table 11.1. Data on the growth of a newly established Mediterranean population of *Saurida undosquamis*, a Red Sea immigrant. Data from Ben-Yami and Glaser (1974, Fig. 5B).

Code year	Catch/effort (kg/h)
1	1
2	2
3	3
4	75
5	78

Table 12.4. Nominal catch-and-effort data from the Gulf of Thailand Trawl Fishery. Data derived from Fig. 7 in Buzeta (1978).

#	Year	Catch $t \times 10^3$	Effort trawl-hours $\times 10^6$
1	1963	190	0.57
2	1964	310	0.98
3	1965	340	1.35
4	1966	360	1.8
5	1967	430	2.4
6	1968	510	3.2
7	1969	510	3.6
8	1970	520	3.7
9	1971	600	5.05
10	1972	680	6.75
11	1973	800	8.6
12	1974	550	8.05
13	1975	700	7.65

APPENDIX II

Errata and updates for:

Pauly, D. 1984. Fish Population Dynamics in Tropical Waters: A Manual for Use with Programmable Calculators. ICLARM Studies and Reviews No. 8, Manila, 325 p.

- p. xv, third line, read 1969 instead of 1979.
- p. 37, Fig. 4.10; t_s should read +0.227 (see also Example 4.7)
- p. 48, last line of step (7) should end with "(the best value of L_{∞} is actually 32.1 as may be inferred from Fig. 4.11)"
- p. 49, step 2; value of b_1 should be -0.001; CHS to compute K.
- p. 53, equation (5.6) should read
$$Z = \frac{1}{C_1 \cdot (t_{\max} - t_c)}$$
- p. 58, line below equation (5.15) should read, "... , of the descending, ..."
- p. 60, left side of equation (5.16) should read " $\ln [N_i(dI_i/dt)]$ "
- p. 61, left side of equation (5.17) should read " $\ln N + \ln (dI/dt)$ ". Also reference to equation (5.13) should be to (5.18).
- p. 62, left side of equation (5.25) should read " $\ln (N_i/t_i)$ "
- p. 68: due to erroneous definition of the time scale in Ebert (1973) the values in Table 5.7 must be multiplied by 11/12 prior to use with equations (5.30 and 5.31) and/or program FB 13 (T.A. Ebert, pers. comm.); Z and K values in Example 5.10 must be corrected accordingly (correct values after new run: K = 0.748 and Z = 3.186).
- p. 75, Fig. 5.16, ordinate scale is in ln units
- p. 80, step (6), last line should read "3.846 ($b = Z/KD$); note that step (7) ignores D, which is here equal to 1.
- p. 81; keystrokes for step (2) are: 30.9 1 2 26 fa. Step (3) should read as follow: "Enter KD; keystrokes: .51 ST01"
- p. 93, delete ref. to Fig. 6.1
- p. 101, Table 7.1, 7th item under "main results" should read "Effects not severe unless M and/or F are very high".
- p. 113, step 4; F and N are twice inverted

- p. 132, equation (9.1) should read $R = 1/(1 + (1/P))$
- p. 140, in first line of last paragraph, read " - maximum sustainable yield and optimum rate of fishing ..."
- p. 140, 143 and 288; equations defining MSY and f_{opt} require the use of absolute value of b, not of b itself.
- p. 141, Fig. 10.2: dots mislabelled, and not positioned correctly (refer to Table 10.1)
- p. 143, equation (10.18) should read " $MSY = \exp(a - 1)/b$ ". Line after equation (10.16) should refer to equation (10.13), not to (10.10).
- p. 145, Fig. 10.5, unlabelled point (near $Z=8$) is point number 1
- p. 146, equation (10.30) has an analytical solution, namely

$$L_{opt} = \frac{L_{\infty} + (Z_{opt} \cdot L'/K)}{(Z_{opt}/K) + 1}$$

and hence does not need to be solved iteratively (J. Hoenig, pers. comm.)

- p. 150, keystrokes for step (2) are: fa 50↑623A 49↑628A 47.5↑520A 45↑513A 51↑661A 56↑919A 66↑1158A 58↑1970A 52↑1317A
- p. 153, first line should read "... Program FB 29 ..."
- p. 158, keystrokes for step (2) are: 80 fa 1↑1A 2↑2A 3↑3A 75↑4A 78 5A
- p. 168, Fig. 12.6, read "Herbivores" for "Hervivores"
- p. 172, in Fig. 12.8B, the equation should read $Y = 808 (1 - e^{-0.311f})$
- p. 175, step (3); estimate Y_p ... etc., for $F_p = 0.8$, not 1.
- p. 178, first equation should read $\phi_i = (n A_1) - [(n-1) A_{1-1}]$
- p. 188, read $\ln(C_B/C_A)$ for $\ln(C_A/C_B)$ (twice on this page); also read "... a pair of gillnets"; note that one must use mesh sizes such that $A < B$.
- p. 193, last step is performed by pressing fe, not E. Also note that K output is actually an output of $K3/b$.
- p. 194, insert "STF2" after step 10 (then save corrected program on new card, and discard old one).

- p. 196, equation (3) should read " $K = -(\ln b)/D$ "
- p. 200, equation (3) should read " $L_{\infty} = a/-b$ "
- p. 216, equation (3) should read " $K = -b_1/D$ "; also note that output of "K" in Program FB 8 is actually an output of KD.
- p. 220, the exponent of equation (5) should be b/D , not $3/D$.
- p. 225, output in step (10) should read "-Z or $-Z/KD$ "
- p. 264, equation (1): denominator should end with an additional bracket.
- p. 268, first line of "Program Description, ..." should read "Program FB 21 ..."
- p. 268, add three missing lines between numerators and denominators of equation (2).
- p. 272, equation (1) should include e^{Zr_1} , not e^{-Zr_1} .
- p. 279, last line read " ... associated with the lowest P/R ratio ... "
- p. 289, initialize program FB 27 through f a, not f b.
- p. 296, equation (3) should read $Z_{opt} = -b_1/2b_2$.
- p. 317, final ref. for Hoenig ("1984") is Hoenig (1983) Vol. 81(4):898-903.
- p. 320, in ref. to Pauly and Ingles (1981) read " ... C. E. Birkeland ... "
- p. 320, final ref. is Pauly, D., J. Ingles and R. Neal 1984. Application to shrimp stocks of objective methods for the estimation of growth, mortality and recruitment-related parameters from length-frequency data (ELEFAN I and II) p. 220-234 in: J.A. Gulland and B.I. Rothschild (eds.) Penaeid shrimps - their biology and management. Fishing News Books, Farnham, Surrey, England, 312 p.

